STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

NAVAL WARFARE RESEARCH CENTER

April 1962

Final Report

AN EXAMINATION OF THE MARINE CORPS REPLACEMENT AND EVACUATION PROGRAM

Prepared for:

OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
WASHINGTON 25, D.C.

CONTRACT Nonr 2332(00)

By: H. B. Wilder, Jr.

SRI Project No. IMU 2167-22

Approved:

A. David Rist

A. DAVID RIST, DIRECTOR NAVAL WARFARE RESEARCH CENTER

for R K Brunnell

C. STANTON BABCOCK, DIRECTOR OPERATIONAL TECHNOLOGY DIVISION

For Official Use Only

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
WASHINGTON 25, D. C.

IN REPLY REFER TO

ONR:493:AS:rg
29 April 1963

From: Chief of Naval Research
To: DISTRIBUTION LIST

Subj: An Examination of the Marine Corps Replacement and Evacuation Program: SRI Project No. IMU 2167-22; forwarding of

Encl: (1) NWRC Unclassified Report, "An Examination of the Marine Corps Replacement and Evacuation Program" dated April 1962

1. Enclosure (1) is forwarded for information. It covers a study, conducted for the U. S. Marine Corps, which, in combination with two other studies, examined issues and relationships associated with Marine Corps Materiel Readiness. The other two studies entitled, "Analysis of Marine Corps Fifth Echelon Repair/Rebuild Program" and, "An Analysis of Training Levels and Their Relationship to Combat Readiness of Troops and Readiness of Equipment" are separately reported.

2. The objective of this study was to examine the USMC Replacement and Evacuation Program and to evaluate the program for: (a) validity among alternative concepts of maintaining materiel readiness, (b) effect on Fleet Marine Force materiel readiness, and (c) effect on field and depot maintenance operations.

S. Shtulman

S. SHTULMAN
By direction

DISTRIBUTION LIST

Commandant of the Marine Corps	(Code AX)	1
	(Code AA)	1
	(Code A01)	1
	(Code A03)	1
	(Code A04)	6
	(Code CH)	6
	(Code AS)	1
	(Code ABF)	3
CMCLFDA, MCS, Quantico, Virginia		7
CG, FMFLant		2
CG, FMFPac		2
CG, 1stMarDiv		2
CG, 2ndMarDiv		2
CG, 3rdMarDiv		2
CG, 1stMAW		2
CG, 2ndMAW		2
CG, 3rdMAW		2
CG, MCB, CamLej		1
CG, MCB, CamPen		1
CG, MCB, 29 Palms		1
CG, ForTrps, FMFLant		1
CG, ForTrps, FMFPac		1
CG, 1stMarBrig		1
MCSA, Phila		1
MCSC, Albany		2
MCSC, Barstow		2
1st FSR		1
2nd FSR		1
3rd FSR		1
Director, Institute of Naval Studies 185 Alewife, Brook Parkway, Cambridge 38, Mass.		1
CNO (OP-03 OEG)		1
(OP-04)		1
(OP-07)		1
ASN(R&D)		1
ASN(Mat'l)		1
Asst SecDef (I&L)		2
ONR (Code 493)		5
ASTIA (Prior approval of ONR Code 493 required before release to other than DOD activities.)		10

PREFACE

This study is one of a group of three studies conducted concurrently on various aspects of Marine Corps materiel readiness. Two of these--Analysis of Marine Corps Fifth Echelon Repair/Rebuild Program and An Analysis of Training Levels and Their Relationship to Combat Readiness of Troops and Readiness of Equipment--are reported separately.

The work on this study was performed at the request of the Assistant Chief of Staff, G4, Headquarters, Marine Corps, and under contract to the office of Naval Research, Naval Analysis Group, Washington, D.C. The study was conducted at Stanford Research Institute in the Naval Warfare Research Center, A. E. David Rist, Director. Program Manager of the three materiel readiness studies was Dr. K. G. Clare. Project Leader for this study was H. B. Wilder, Jr. and research assistance was provided by D. V. Graves and V. J. O'Day. Technical supervision of the project was provided by the Plans and Operations Division (Code A04J), G4, Headquarters, USMC, under Col. W. T. Bigger, USMC. Project monitors were Col. W. K. Schaub, USMC, of ONR, Mr. S. Shtulman of ONR, and Lt. Col. T. H. Rogers, Jr., USMC, and Lt. Col. Thomas D. Stockwell, Jr., USMC of Headquarters USMC.

In the course of the work visits were made to Headquarters, USMC, Washington, D.C.; USMC Supply Activity, Philadelphia, Pa.; Marine Corps Supply Center, Albany, Ga.; Marine Corps Supply Center, Barstow, California; Headquarters, FMFPAC; First Marine Division (Reinf); Second Marine Division (Reinf), N.C.; First Marine Brigade, Third Marine Division (Reinf); First Marine Aircraft Wing; the U.S. Navy Bureau of Yards and Docks, Washington, D.C.; The Office of the Comptroller, Department of the Navy; and the Office of Chief of Ordnance, U.S. Army, Washington, D.C.

The warm cooperation of the officers, noncommissioned officers, men, and civilian officials of these organizations is greatly appreciated.

CONTENTS

For Official Use Only

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

I INTRODUCTION

Since FY59, the USMC Replacement and Evacuation Program has been the primary equipment replacement system for the Fleet Marine Force. It is a method of annual exchange by which major mission-essential combat equipment is replaced on the basis of fixed age/use criteria and evacuated to 5th Echelon for repair/rebuild and eventual reissue.

The Replacement and Evacuation Program is addressed to maintaining serviceability of equipment. Considerations of obsolescence are important only insofar as they determine what types of equipment are included in a given program year. Except for the fact that replacement equipment may have been brought more up to date by modification, the new or rebuilt replacement is simply a more serviceable version of the worn unit it replaces. There must be a close interrelationship between the management of the 5th Echelon Repair/Rebuild Program and that of the Replacement and Evacuation Program, but the two operate separately and merit separate justification. In the unlikely event that the USMC 5th Echelon Program was inactivated, there would still be a need for equipment replacement programing for the Fleet Marine Force.

Although the effectiveness of the Replacement and Evacuation Program has great implications for the Fleet Marine Force in combat, it operates in garrison and cannot be translated to the combat objective area. The program is designed for peacetime or cold war operation and it seeks to ensure annual inputs of fully serviceable equipment into the in-use inventory of the FMF within the constraints of nonwartime budgets. Essentially, the contribution of the Replacement and Evacuation Program must be to force in readiness.

To be effective, an FMF replacement program must provide the maximum combat readiness obtainable for FMF materiel. The primary mission of the Fleet Marine Force is to provide a force in readiness. FMF must be ready on minimum notice to enter a variety of combat environments in a variety of assault modes. In order that this force in readiness mission can be carried out, it is imperative that force materiel be in a high state of readiness at all times.

In operation the program should have continuity. It should provide for the long-range requirements of materiel readiness as well as the current ones. For example, avoid block unserviceability. It should permit the tactical commander to plan his future use and maintenance of equipment intelligently. The U.S. Marine Corps is essentially an organization of professionals. In order to derive maximum benefits from this professionalism, a long-term program clearly understood by field managers should be planned.

The program should be realistic. It should be based on management criteria which accurately measure or predict unserviceability. It must be such that the Marine Corps can support the program for its required duration. While its basis remains the need of the Fleet Marine Force, the program must be compatible with the capabilities of support organizations in the Marine Corps. If these are prevented from performing their mission, ultimately the position of FMF will suffer, since these support organizations exist only to support FMF.

The program should be responsive. Additional to the obvious fact that it must respond to the stated needs of FMF, the program should be sufficiently flexible to respond to changes in these which occur within the program cycle. The Marine Corps is an austere organization logistically. It maintains the minimum logistics organization needed to meet the requirements of combat efficiency. To be truly responsive, the program should be simple to permit its uniform administration throughout the Marine Corps. If complexity cannot be avoided, the complex features should be as far removed from the tactical commander as possible.

The program should be economical. It should be organized to obtain maximum use of the equipment, manpower, and facilities available. There may be some uneconomical practices necessary to maintain levels of readiness, but where thrifty administrative practices will achieve the desired readiness, not to follow them erodes the readiness capability of the Marine Corps.

The objective of this study was to examine the validity of the Replacement and Evacuation Program relative to alternative concepts of maintaining readiness of major materiel. The Replacement and Evacuation Program was analyzed in terms of its effect on and place in the Marine Corps Materiel Program. Since the basis for the Replacement and Evacuation Program is age/use criteria for equipment replacement nomination, the relationship of these factors to equipment serviceability was examined. The study team investigated the relationship of the program to field and depot maintenance operations and the effect of the program on Fleet Marine Force materiel readiness. Finally, a survey was made of the academic literature of the field and of equipment replacement programing for other Department of Defense activities and for industry to determine their applicability to the Marine Corps problem.

II SUMMARY AND CONCLUSIONS

The USMC Replacement and Evacuation Program is a system of replacing Fleet Marine Force major combat equipment on the basis of fixed age/use criteria and evacuating the worn equipment to 5th Echelon for eventual reissue after repair/rebuild. Organized in 1958, the program is basic in Marine Corps planning for materiel for force in readiness. The original aims of the program were to improve FMF materiel readiness, avoid recurrence of block unserviceability of combat equipment, reduce field echelon repair backlog, and stabilize evacuation of unserviceable assets to 5th Echelon by a scheduled phasing of equipment. A more recent aim has been to retain in FMF service materiel which has maximum residual service life for combat and/or minimum maintenance requirements.

The program has undoubtedly improved Fleet Marine Force materiel readiness. It has insured the field commander a full table of equipment and has provided him a partial basis for equipment management. A considerable number of items of combat equipment have been replaced as a result of the program which probably would not have been replaced otherwise. This has provided an opportunity to eliminate from the in-service inventory equipment approaching unserviceability and has reduced the deadline of FMF equipment awaiting repairs. However, the benefits of the R&E Program have been short term in character, and a regular program supportable over the long term has not yet evolved.

Coincident with the R&E Program, unserviceable assets have backlogged at 5th Echelon. Equipment has been replaced more rapidly than it could be restored to serviceability by 5th Echelon. As a result, the serviceable assets available for issue have been reduced to a point where equipment is now included in the R&E Program primarily on the basis of such availability rather than on FMF need. Annual replacement of a percentage of total equipment required in service, so as to avoid block unserviceability, has been all but abandoned.

Age/use criteria have been the basis for both nominating and actually replacing equipment items since the R&E Program was organized. Analysis of the relationships between either use or age and equipment unserviceability indicates that these criteria used alone are inaccurate predictors for replacing individual equipment. The administrative procedures adopted to overcome the effect of using these criteria for actual replacement have vitiated the advantages of the program.

Some of the disadvantages of the R&E Program as now organized are:

1. There is a requirement for long-range nomination of unserviceable equipment for replacement. This nomination is based on an inaccurate predictor--age/use criteria.

2. The premature evacuation of equipment is encouraged, since the arrival of replacement equipment requires the evacuation of a like equipment, whether it is unserviceable or not.

3. Since nominating an item of equipment for replacement schedules that equipment for evacuation, the user unit tends to withhold maintenance, especially repairs, on equipment items nominated for R&E. Thus the administrative device of nomination accelerates unserviceability of equipment included in the program.

4. Because of the difficulty of comparing equipment condition of various units, especially units geographically separated, and because once replacement equipment is distributed like equipment must be rotated to 5th Echelon, the R&E Program hazards evacuating better equipment than some retained in FMF service.

5. The R&E Program contributes to the backlog of unserviceable assets awaiting rebuild at 5th Echelon.

6. The R&E Program is complex to administer.

7. The R&E Program tends to pervade all aspects of FMF materiel so that the contribution of this program and that of other improvements in the Marine Corps materiel program are difficult to isolate and evaluate.

Predicted average unserviceability--which is what results from the nominating process--is useful for planning over-all assets availability but is not a sound basis for replacement of individual equipment items. It fails to take into account the great variability between individual equipments making up the average. If assets not requiring evacuation can remain in use and the replacements programed for them can be conserved until needed, not only would waste of useful equipment life be prevented, but serviceable replacements would be available when the actual need for rotation occurred. It is possible to "manage by the average," but only if replacement is made by individual equipment.

FMF equipment should be programed for replacement on the basis of the availability of resources, including the serviceable assets available for issue; the organic and field maintenance capability of the FMF; and on the potential for intelligent materiel programing by user units in the FMF.

Modification of the present program to a dynamic float replacement system could correct R&E Program deficiencies while retaining present advantages. In a dynamic float system, all replacement equipment would be held in an equipment float or pool by field maintenance echelon until actual need for replacement occurred instead of being sent direct to user units for immediate replacement of nominated items. All evacuation of equipment in an area would be managed at field maintenance echelon. The size and composition of this float would be dynamic in that it would reflect the varying needs of the FMF units supported. The method of calculating the float would be based on a comparison of the number of unserviceables generated by the supported units and the maintenance capacity of field maintenance. The rate of evacuation of equipment to rebuild would be controlled by standards issued by HQMC.

The dynamic float replacement system would offer the following advantages:

1. Since replacement equipment would be prepositioned on the basis of insuring supported units a full table of equipment serviceable for combat, more useful service life could be used up in equipment prior to replacement without hazarding mount out with unserviceable equipment.

2. Equipment programed for replacement can be conserved until actual need for replacement occurs.

3. There is no need for accurate long-range forecasts concerning individual equipment condition. With replacement assured when the actual need occurs, unit commanders can concentrate on obtaining maximum equipment use through good materiel management.

4. Evacuation decisions in a designated geographic area are made at one point, 4th Echelon. This is the point best qualified to select the worst equipment in the area. Since there are relatively few 4th Echelon units and these are the senior field maintenance activities, program management of common standards of unserviceability between geographic areas is simplified.

5. Receipt of unserviceable assets at 5th Echelon in more uniform condition would improve rebuild efficiency. This in turn would provide more serviceable assets for reissue through the float for a given expenditure of repair funds.

6. The method of float calculation affords an opportunity to isolate and evaluate various contributions to materiel readiness.

A set of standards and definitions of unserviceability must be developed for Marine Corps materiel management programs that are stated in terms meaningful to all echelons of command and maintenance. The material from which such definitions could be developed is already available in various Marine Corps documents, but it must be adapted to a format which meets the need of a specific replacement program.

III THE REPLACEMENT AND EVACUATION PROGRAM

Background

In 1957, materiel readiness of the Fleet Marine Force, particularly the 2nd Marine Division, had so deteriorated that logisticians of Headquarters, U.S. Marine Corps, felt there was clear need for an improved program for equipment replacement. Force materiel was approaching block unserviceability. Several factors had contributed to the situation. All of the major equipment of the force was of a like age, the result of the Korean conflict procurements. Decreasing budget and manpower levels were reflected in reduced organic and field maintenance performance. Equipment deadlines were growing. At the same time, the two Marine Corps Supply Centers were hampered by a lack of predictable unserviceable assets for induction to rebuild.

The Replacement and Evacuation Program began in FY58 for Fleet Marine Force Atlantic and in FY59 became FMF-wide. The key scheme of the program was to replace equipment while it was economically repairable and evacuate the worn equipment to rebuild. Equipment would be replaced before it reached complete unserviceability. Hence the near-time requirement for force materiel readiness would be insured. Future materiel readiness would be achieved by cycling the used equipment through rebuild. Thus more than one service life would be obtained from individual equipment during the life of the equipment type.

The original plan was to replace, annually, a fairly fixed percentage of the tables of equipment of the FMF. These percentages were a function of the age/use criteria for rebuild of individual equipment types--criteria arrived at by the professional judgment and experience of the headquarters specialists in the various equipment fields. For example, the age criteria for the M38A1 jeep was 4-1/2 years. Thus it was planned to rotate 22 percent of the FMF jeeps annually in order to replace all FMF jeeps in the course of 4-1/2 years. To allow for unequal use of equipment, an equivalent-use criterion was designated--in the example given, 20,000 miles. Criteria were subject to review if subsequent field experience indicated they did not meet requirements. Since most of the equipment in service was of equal age, the plan was to rotate those in poorest condition first. For flexibility, the FMF commanders were each allowed a discretionary change of plus or minus 10 percent of their annual quota without reference to Commandant, Marine Corps.

Two provisions to retain managerial control in Headquarters, Marine Corps, were established. First, the replacement schedule was separated into annual programs to permit periodic reviews, and second, except for requirements resulting from changes in tables of equipment, the FMF was expected to satisfy all normal requirements for equipment types included in the program from the annual R&E quota. Except for these controls, the program was considered to be almost automatic. In theory, the field commander was afforded not only inputs of fully serviceable equipment and a means of evacuating worn equipment, but also planning factors with which to establish materiel programs. Also, a level predictable flow of unserviceable assets to the 5th Echelon rebuild program was assured, again in theory.

The long-term aims of the original program were to improve materiel combat readiness, avoid recurrence of block unserviceability of FMF equipment, reduce field echelon repair backlogs, and systematize the evacuation of assets to 5th Echelon by a scheduled phasing of equipment.

During the years the Replacement and Evacuation Program has been in operation, some rather drastic changes have been made in the system. Some of these changes occurred because of modernization programs. Small arms, for example, were dropped because the standard Marine-issue equipment of this type reached the end of its service life and was replaced by a new family of equipment. In other cases, e.g., general supply items, it was determined that the equipment was not suited to the philosophy of criteria replacement but was suited to component replacement. The entire family of engineer equipment was dropped from the program beginning FY62, partly because much of the equipment was not suited to rebuild. Much engineer equipment is adapted from commercial equipment, and since there is a constant redesign and turnover of commercial models, after one service life, the Marine Corps has difficulty in obtaining repair parts in the numbers needed for complete rebuild. Each successive rebuild tends to aggravate this condition. At the same time, rebuilt engineer equipment becomes increasingly obsolescent compared to its commercial counterparts.

For the most part, changes to the original Replacement and Evacuation Program have occurred because of the decreasing serviceable asset position of the Marine Corps. The program proved unsupportable in its original form because it drained off serviceable assets at a greater rate than they could be furnished. Table 1 illustrates the pattern of decreasing support provided by the Replacement and Evacuation Program to the two FMF commands.

As the inability of the Marine Corps to support the Replacement and Evacuation Program became apparent, changes were made which tended to complicate program administration and to modify the original aims of the program. A regular program supportable over the long term has not yet evolved. As a result, types and numbers of equipment are now included in R&E primarily on the basis of availability of the equipment, rather than on the basis of the FMF need. FMF commanders are no longer permitted discretionary increases in their annual quota, and phasing equipment turnover as a percentage of the total number of items required in service (to avoid block unserviceability) has been all but abandoned. Now, nominations for annual replacement must not only meet age/use criteria, they must be predicted to reach a state of unserviceability by the time of replacement. The immediate aim of the current program is to keep materiel which has maximum residual service life and/or minimum maintenance requirements in the Fleet Marine Force. Satisfying both original long-term and current short-term aims by the present program, in some cases, appears to be mutually defeating.

Effectiveness

Isolating the contribution of the R&E Program to FMF materiel readiness is extremely difficult. Detailed records of sufficient purity to permit direct comparison of equipment status before and after the inception of R&E are not available. Coincident with the R&E Program, there have been many changes in the USMC which have affected the readiness of equipment. These include changes in the supply system, revisions in 5th Echelon repair policies, reorganization of the structure of Force Service Regiment, changed manning policies, increases in the training tempo, and intensification of the readiness state (including increased deployment of units); all have affected the use, maintenance, and condition of equipment and the over-all R&E Program. However, it is apparent that the R&E Program has made a significant contribution to materiel readiness. In each field interview the question was asked, "What has been the effect of the R&E Program on combat readiness; how can we measure this effect?" The answers received differed only in form. There was unanimous agreement that the effect was difficult to measure but that R&E had improved readiness of materiel for combat. The following answer from an FMF Combat Service Support Unit Commander is typical, "Although there is no known proof of the effect of the R&E Program on the combat readiness of the units which this program is supporting, it is the

Table I

NUMBER OF EQUIPMENT ITEMS APPROVED FOR REPLACEMENT AND EVACUATION, BY FISCAL YEAR

	FMFPAC	FMFLANT
Communications-electronics		
FY59	2,112	1,391
FY60	1,305	1,320
FY61	832	471
Subtotal	4,249	3,182
FY62	811	471
Total	5,060	3,653
Motor transport		
FY59	1,449	440
FY60	1,733	549
FY61	609	279
Subtotal	3,791	1,268
FY62	236	142
Total	4,027	1,410
Ordnance		
FY59	647[a]	45
FY60	145	65
FY61	118	60
Subtotal	910	170
FY62	54	39
Total	964	209
Engineer		
FY59	107	93
FY60	140	93
FY61	97	64
Subtotal	344	250
FY62	0	0
Total	344	250
General supply		
FY59	3	2
FY60	3	0
FY61	0	0
Subtotal	6	2
FY62	0	0
Total	6	2
Total Pacific	10,401	
Total Atlantic		5,524
Grand Total	15,925	

a. Includes 270 BAR and 226 MG 30 cal.

Source: CMC Annual Replacement and Evacuation Program letters for fiscal years shown.

consensus of this Headquarters that the R&E Program has greatly reduced maintenance workload and has enhanced the combat readiness of the supported units."

Table I summarizes the equipment approved for replacement by R&E for fiscal years 1959, 60, 61, and 62. During the first three full years of operation, about 5,000 pieces of tactical motor transport, nearly 7,500 items of communication electronics gear, almost 600 units of major ordnance (including tracked vehicles), and over 600 items of engineer equipment were programed for the Fleet Marine Forces as a result of the R&E Program. Table II contains a list of items approved for R&E in fiscal years 1959, 60, 61, and 62. Naturally, this influx of new or rebuilt equipment has made a great contribution to FMF materiel readiness.

One instance of equipment replacement timing provides a striking example of the program's effect. This is shown in Table III which presents the First Marine Division tractor equipment deadline by months from January 1959 through April 1961. In January 1959 there were 23 TD-18 (AD) tractors on the First Marine Division deadline. One year later, after an infusion of R&E replacements, the deadline was 2. Subsequently, when replacements were delayed, the deadline increased in October to 19; in March 1961, it dropped to 8. According to the member of the Division special staff who provided the data, the decrease in deadline was attributable to the R&E Program.

Although many features of the original program have been changed, one of its most important aspects has endured: the user unit is provided with a piece of replacement equipment before it is required to evacuate the worn one. Thus the commander is assured a full table of equipment. This is a major advantage of the R&E Program and one which any future FMF replacement program should seek to retain.

Limitations

Currently the R&E Program operates on a calendar represented by the time bar shown in Figure 1. During February and March preceding the program year, unit commanders are required to inspect equipment which meets the age/use criteria specified. From the equipment which will meet the criteria, only items which are predicted to become unserviceable during the program year are nominated for replacement. These nominations are collated up through the echelons of command and forwarded to Commandant, Marine Corps, by late March. On receipt of the nominations, Headquarters personnel determine from the serviceable asset position projected for the

Table II

APPROVED REPLACEMENT AND EVACUATION PROGRAMS FOR
FMFPAC AND FMFLANT, BY EQUIPMENT ITEMS
(Fiscal Years 1959, 1960, 1961, and 1962)

Items of Combat Equipment	FMFPAC				FMFLANT			
	FY62	FY61	FY60	FY59	FY62	FY61	FY60	FY59
Engineer								
Bath unit, 24 head		6[a]	24[a]	27[a]		3[a]	2[a]	2[a]
Boat bridge erection, 27 ft		1[a]						
Compressor air, trailer mtd., GED 105 CFM		12[a]	8[a,b]	7[a]		2[a]	5[a]	6[a]
Crane, shovel crawler mtd., Bay City, M-37		5[a]	13[a]			2[a]	1[a]	2[a]
Crane, tractor towed, M-20		2[c]	1[c]					
Drill, pneumatic drifter		1[a]						
Distributor, bituminous, trk. mtd.		1[a]	1[a]					
Floodlight set, electric, trlr. mtd.		7[a,d]	6[a]	10[a]		14[a,b]	6[a]	5[a]
Generator, 30 kw, DED, trlr. mtd., ac (37.5 kva)		2[b,c]	1[c]	8[e]		6[b,c]	4[b,c]	7[a]
Grader, road, towed		3[a,d]				1[a]		
Mixer, concrete, trlr. mtd.		3[b,f]				2[a,b]	1[b,c]	
Roller, motorized		2[a]						
Saw, radial, overarm, woodworking, trlr. mtd.		2[a,b]	1[d]	2[a]		1[a]	1[d]	1[a]
Tractor, full-tracked, TD-18 w/angledozer		42[a,d]	30[a,c]	5[a]		12[b,c]	12[a,c]	
Tractor, walking, power driven		1[a]						
Welding machine, elect, arg. trlr. mtd.		1[a,f]	5[a,b]	4[a]		6[a,b]	1[a]	1[a]
Tractor, full-tracked, TD-24, w/AD		3[a]	4[a]	1[a]		3[a,d]	1[a]	2[a]
Tractor, full-tracked, T-18, w/BD		3[c]	9[a,c]	11[a]		4[b,c]	4[c]	
Crane shovel, crawler mtd., Koehring mdl. 2N			12			2[a,d]	4[a]	3[a]
Compressor, air, ptbl., DED, 315 CFM			1[a,b]				1[a]	1[a]
Pump, deepwell, 60 gpm			4[c]				2[a]	5[a]
Pump, set, GED, 55 gpm			18[c]				7[c]	7[a]
Refrigerating unit, ME-10			3[a]	6[a]			15[c]	12[a]
Roller, tandem			1[c,d]					1[d,e]
Roller, sheepsfoot			6[c]					1[a]
Roller, pneumatic tired			1[a]					1[a]
Rooter, road f/tractor, med.			1[c]					1[a]
Spray, set, paint			2[c,d]				2[d]	4[a]
Distillation unit, DVC-8M				4				
Water purification equip. 25 gpm diatomaceous earth type				2[a]			4[a]	
Generator, ac, GED, trlr. mtd. (9.4 kva) 7.5 kw				1[c]		6[b,c]	5[c]	4[a]
Filter, separator				1[a]				
Meter, manifold				4[a]				

a. Evacuate to Supply Center.
b. Limited standard or substitute item available.
c. Cannibalize and/or dispose of locally, send test equipment to depot.
d. Available during FY __.
e. Item itself will be evacuated, repaired, and returned.
f. Not available in amount requested.

Table II (continued)

Items of Combat Equipment	FMFPAC				FMFLANT			
	FY62	FY61	FY60	FY59	FY62	FY61	FY60	FY59
Engineer (cont.)								
Pump, self-priming, centrifugal				14[a]				
Distillation unit, 85 gph							4[a]	
Grader, motorized, Adams mdl. 550							1[a]	
Refrigerator, 8 cu ft, mech. household							6[c]	
Saw, chain, ptbl. 36"							3[a]	7[c]
Crane, trk. mtd. 6 x 6							1[a]	1[a]
Tractor, DED, Hystaway, TD-18-181								1[a]
Tractor, DED, TD-24				1[a]				2[a]
Tractor, TD-18-181								16[a]
Water purification equip.								7[a]
Scraper, 16 cu yd								1[a]
Refrigerator, kerosene, 8 cu ft								5[a]
Refrigerating unit, MQ51E								5[a]
Truck, firefighting								
General supply								
Laundry unit, trlr. mtd. (2-trlr. type)			1[a]	2[a]				1[a]
Shoe & textile repr. shop, trlr. mtd. (2,000 man)			2[d]	1[a]				1[a]
Fog generator					1[a]			1[a]
Motor transport								
Truck, ambulance, front line, 1/4 T, 4 x 4, M170		30[a]	22[a]	13[a]		9[a]	9[a]	9[a]
Truck, ambulance, 3/4 T, 4 x 4, M43		16[d,f]	8[a]	13[a]		7[a]	5[a]	6[a]
Semitrailer, cargo, 12 T, 4 whl. M127		21[a]						
Truck, utility, 1/4 T, 4 x 4, M38A1		137[d,f]	406[d,f]	329[a]		65[d,f]	159[f]	182[a]
Truck, cargo, 2-1/2 T, 6 x 6, LANT M34 M35	103[a]	257[a]	173[a]	306[c]	80[d]	65[d,f]	198[a]	104[a]
Truck, gasoline tank, 2-1/2 T, 6 x 6, M49	7[a]	14[d]	8[d]	28[d]		9[d]	7[a]	7[a]
Truck, dump, 5 T, 6 x 6, M51	6[n]	68[d]	39[a]	40[a]	22[a]	3[a]	27[a]	27[c]
Truck, tractor, 5 T, 6 x 6, M52	6[a]	34[a]	11[a]	13[a]	4[d]	5[a]	9[a]	10[c]
Truck, medium wrecker, 5 T, 6 x 6, M62	22[d]	13[d]	13[d]	19[d]	6[d]	5[a]	6[d]	5[a]
Chassis, truck, 5T, 6 x 6, w/winch, M40		11[d]				2[d]	2[d]	
Truck, firefighting, 2-1/2 T, 6 x 6, 500 gal		6[d,f]			1[d]			
Truck, firefighting, M38A1, SK-106			1[a]					
Chassis, truck, 2-1/2 T, 6 x 6, M-44-VQ-17A		2[a]						
Carrier, light weapons, infantry, 1/2 T, 4 x 4, M274			50[d]				4[d]	
Trailer, cargo, 1/4 T, 2 whl., M100			250[a]	236[a,c]				
Trailer, greasing, 1/4 T, 2 whl.			34[d]	37[a]				
Trailer, HPCU, 1/4 T, 2 whl.			19[a]	32[a]				
Trailer, cargo, 3/4 T, 2 whl., M-101			113[a]	45[a]				
Trailer, cargo, 1-1/2 T, 2 whl.			225[a]	77[c]				
Truck, cargo, 3/4 T, 4 x 4, M37			168[a]	95[c]		55[d]	79[a]	42[c]
Truck, cargo, 5T, 6 x 6, M54	77[d]		193[a]	126[a]	29[a]	44[d]	31[a]	48[a]
Truck, forklift, 4,000 lb, gas				7				
Truck, forklift, 6,000 lb, gas				8				
Trailer, firefighting, 500 gpm				4[a]				
Trailer, stockroom, 2 T, 4 whl.				15[e]				
Truck, firefighting, extinguisher, SP						2[d]		

Table II (continued)

Items of Combat Equipment	FMFPAC FY62	FMFPAC FY61	FMFPAC FY60	FMFPAC FY59	FMFLANT FY62	FMFLANT FY61	FMFLANT FY60	FMFLANT FY59
Motor transport (cont.)								
Semitrailer, 12 T, 4 whl., cargo						8[a]		
Lubricating and servicing unit							6[a]	
Cleaner, steam, trlr. mtd.							7[a]	
Landing vehicle, wheeled (DUKW) M353	15[a]							
Ordnance								
Gun, 155 mm, SP, M53	4[a]	4[a]	1[a]	4[a]	1[a]	5[a]		
Howitzer, 155 mm, on carriage M1A1	1[a]	8[a]	7[a]	1[a]	3[a]	3[a]	1[a]	1[a]
Howitzer, 8", SP, M55	6[a]	6[a,f]	2[a]		3[a]		1[a]	1[a]
LVTP 5	14[a]	42[d]	53[d]	27[a]	20[a]	20[f]	25[a]	25[a]
LVTH 6		2[a]	5[a]					
LVTR 1		3[a]	2[a]	1[a]	1[a]	1[a]	1[a]	1[a]
Rifle, mult, 106 mm, SP, M50 (ONTOS)		25[d,f]	26[a]	13[a]		10[d]	11[a]	
Tank, flamethrower, M67	3[a]	4[a,f]	2[a]	2[a]		2[d]	2[a]	2[a]
Tank, 90 mm, M48A1	20[a]	15[a]	14[a]	13[a]	8[a]	17[a]	14[a]	11[a]
Tractor, cargo M8A1		4[a]	12[a]	15[a]				
Vehicle, tank, recovery, M51	5[a]	5[a]	3[a]	2[a]	2[a]	1[a]	1[a]	1[a]
Howitzer, 105 mm, on carriage, M2A1, M2A2			18[d]	49[a]			8[a]	
BAR, Cal .30				270[a]				
MG, Cal .30				226[a]				
Gun, twin 40 mm, SP, M42				23[c]				
Launcher, 762 mm, rocket M-33				1[a]				
LVTP5 (CMD)	1[a]				1[a]	1[a]	1[a]	1[a]
Launcher, rocket, 4.5", M-21								2[c]
Communication-electronics								
Combat info central, AN/TSQ-6	1[d]	2[d]	4[a,e]	2[a]		2[d]	1[e]	1[a]
Direction finder set, AN/TRD-12		4[c]	6[a,e]	2[a]		3[c]	1[e]	1[a]
Generator set, diesel eng. PU-239, D/G		17[a,f]	20[a]	20[a]		9[a]	10[a]	9[a]
Motor generator, PU-328 A/U		1[d]	1[d]					
Power unit, PE-214	4[a]	8[c]	1[c]		8[c]	4[c]	8[c]	8[c]
Public address set, AN/TIP-1A		2[c]	6[a]	6[a]		1[c]	6[a]	7[a]
Public address set, AN/TIP-2		1[c]		2[a]			3[a]	
Radar set, AN/TPS-15X		9[c]				2[c]		
Radio set, AN/MRC-36		2[d]	4[d]	5[a]		6[d]	4[d]	2[a]
Radio set, AN/MRC-37		24[d]	35[d]	14[e]		10[d]	12[d]	12[a,e]
Radio set, AN/MRC-38		31[d]	45[a]	18[e]		2[illegible][d]	20[a]	19[e]
Radio set, AN/MRC-62		11[e]	11[a]	6[e]		10[d]	10[a]	9[a]
Radio set, AN/MRC-40		5[d]	22[d]	8[a]		5[d]	4[d]	3[e]
Radio set, AN/GRC-48		2[d,f]	7[a]	5[a]		5[d]		
Radio receiver, RBZ		4[c]				11[c]	5[c]	5[c]
Radio receiver set, AN/TRR-5		17[c]	3[a]			7[c]	4[c]	4[a]
Switchboard, TP man, SB-86/P	7[a]	7[a]	10[a]	4[a]	8[c]		4[a]	5[a]
Telephone, EE8	269[c]	653[c]		796[c]	270[c]	325[c]	370[c]	361[c]
Terminal telegraph, TP, AN/TCC-14		29[d]	15[a]	8[a]		24[a]	15[a]	14[a]
Inter-communication set, AN/GIC-1		3[c]						
Detecting set, AN/PRS-4			3[a]	12[a]			8[a]	8[a]
Detecting set, mine, AN/PRS-3	15[c]							
Detecting set, AN/PRS-3A			17[a,b]				8[b]	8[a]

For Official Use Only

Table II (concluded)

Items of Combat Equipment	FMFPAC FY62	FMFPAC FY61	FMFPAC FY60	FMFPAC FY59	FMFLANT FY62	FMFLANT FY61	FMFLANT FY60	FMFLANT FY59
Communication-electronics (cont.)								
Generator set, diesel eng., PU/273 A/G			3[a,b]	1[c]			1[b]	1[a]
Public address set, AN/TIQ-2A			17[a]				2[a]	1[a]
Radar set, AN/MPQ-10A			2[e]	1[e]				
Radar set, AN/MPS-11A			3[d]	2[e]				
Radar course dir. control, AN/MPQ-14A			1[a]					
Radio receiver set, AN/URR-23A			16[a]	4[a]			1[a]	1[a]
Radio set, AN/GRC-9			137[a]					
Radio set, AN/MRC-6C			68[a]	89[b]			37[a]	42[a]
Radio set, AN/MRC-30			10[a]	10[a]			10[a]	11[a]
Radio set, AN/MRC-32			13[a]	14[a]			10[e]	11[a]
Radio set, central, AN/MRC-35A			5[e]	4[a]			10[e]	11[a]
Radio set, AN/PRC-6	200[a]		251[a]	300[a]	72[c]		230[a]	239[a]
Radio set, AN/PRC-8	18[a]		16[a]	39[a]	11[c]		12[a]	14[a]
Radio set, AN/PRC-9	132[a]		89[a]	248[a]	17[c]		96[a]	95[a]
Radio set, AN/PRC-10A	148[a]		268[a]		66[c]		240[a]	258[a]
Radio set, MAY-1			53[e]				22[e]	35[e]
Reperforator TT set, AN/GGC-3			3[a]	9[a]			7[a]	8[a]
Switchboard, SB-22/PT			88[a]	108[a]			59[a]	59[a]
Teletypewriter, set, AN/TGC-6			39[e]	46[a]			23[e]	23[a]
Wind measuring set, AN/MMQ-1			2[a]					
Radar set, AN/TPS-15	4[f]		6[a]	1[a]	4[f]		1[a]	
Generator set, diesel eng., PU-344			4[a]					
Public address set, AN/PIQ-3			1[a]					
Power unit, PE-75				45[c]				26[c]
Power unit, PE-210				31[a]				18[a]
Power unit, PE-214-C				14[c]				
Radar beacon, AN/TPQ-7				3[e]				1[a]
Radio set, AN/GRC-9-Z				116[a]			57[a]	55[a]
Radio set, AN/MRC-63				1[e]			3[a]	3[a]
Radio set, AN/GRC-7				19[a]			3[a]	3[a]
Radio set, AN/PRC-10				230[a]				
Radar beacon, AN/TPN-7					1[a]	1[a]	2[a]	
Amplifier power supply, AM-598A/U	9[c]				10[c]	15[c]		
Power supply, PP-388A/U						10[e]		
Truck, V-18A/MTQ							2[a]	
Electronics repair shop, AN/MSM-3				4[a]				1[a,d]
Power unit, PU-357/U								28[a]
Public address set, AN/TIP-X								1[c]
Truck, V-18A/MTG								2[a]
Radio set, AN/GRC-5								1[a]
Radar set, AN/MPS-16					4[a]			
Combat info central, AN/TSQ-5	2[d]							
Radar set, AN/MPS-16A	2[a]							

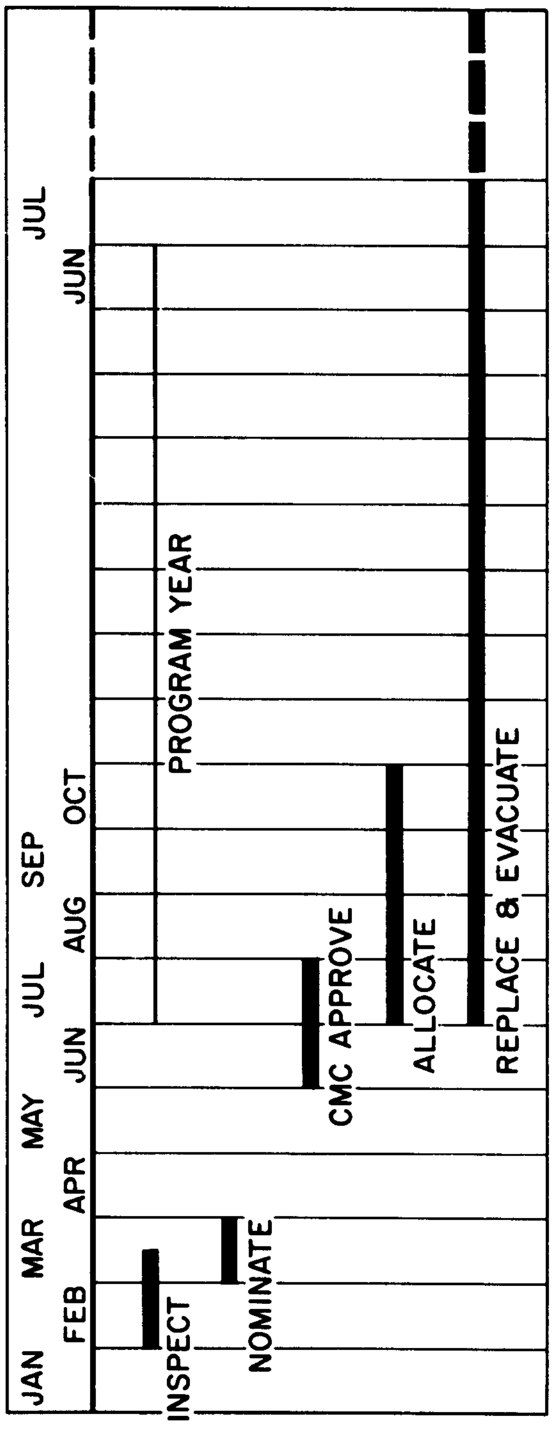
Source: CMC Annual Replacement and Evacuation Program letters for fiscal years shown.

Table III

FIRST DIVISION TRACTOR DEADLINE
(January 1959-April 1961)

	No. of Tractors TD-18 (AD) (T/A No. 31710)	No. of Tractors TD-18 (BD) (T/A No. 31715)	No. of Tractors TD-24 (AD) (T/A No. 31720)	No. of Tractors TD-18A (Hyst.) (T/A No. 31730)
1959				
January	23	--	5	1
February	12	--	3	--
March	8	3	3	--
April	4	1	--	1
May	8	--	--	--
June	6	--	1	--
July	8	--	3	--
August	12	--	5	--
September	19	1	6	--
October	7	--	3	--
November	9	--	2	--
December	7	4	1	--
1960				
January	2	2	--	--
February	--	2	--	--
March	3	2	1	--
April	2	--	--	1
May	8	7	1	--
June	8	4	1	--
July	9	4	--	--
August	18	2	3	1
September	13	4	3	--
October	19	--	3	--
November	12	2	4	--
December	8	2	1	1
1961				
January	12	2	1	--
February	15	1	2	1
March	7	1	1	1
April	8	--	1	2

Source: First Marine Division Engineer Office records.



SOURCE: NWRC, Stanford Research Institute.

FIG. 1 REPLACEMENT AND EVACUATION PROGRAM CALENDAR

For Official Use Only

program year what numbers of what equipment items can be supported. The approved list is distributed through annual R&E letters issued in June or July.

Where HQMC changes from the nominations have been required, an allocation of the approved equipment to individual units is required back down the echelons of command. This occurs between July and October, depending on the degree of change required. Only at receipt of allocation does the individual unit commander know what equipment he may expect to receive for the program year; when he may receive it is another matter, perhaps early in the program year, perhaps not until the next year. The problem facing the nominating unit commander is that he must predict in February and March the condition the individual pieces of equipment will be in any time four to sixteen months hence and must do so mostly on the basis of an inaccurate estimated age/use factor.

In the unlikely event the commander has the necessary prescience to make this long-range forecast accurately, another program rule complicates his problem. R&E is the sole source of equipment included in the program. If a piece of equipment younger than criteria and therefore not included in the original nomination becomes so unserviceable as to require evacuation during the cycle, it must be replaced either from the original quota or from a new quota that must be requested. Assume the commander has forecast correctly and that the nominated units as well as the noncriteria equipment require replacement. If he replaces from the original quota, he must choose between unserviceables and make the best of a bad choice by replacing only one. If he requests a new quota, he embarrasses the serviceable asset position of the Marine Corps because all assets available have already been distributed.

In either case, the tactical unit must retain unserviceable equipment for some period, and this erodes the materiel readiness of that unit and adversely affects the force in readiness. The solution to the problem is fairly obvious. If there is any doubt as to the future condition of the equipment, the tendency is to nominate it. Once the replacement equipment is received, there is no alternative to evacuating a like piece, whether the like piece of equipment is a valid candidate for 5th Echelon repair or not. In this respect the program tends to encourage premature evacuation of equipment.

In recognition of this situation, the FMF commanders are authorized to reduce the annual replacement allowance if, prior to shipment of replacements, the equipment approved for rotation does not appear to be approaching unserviceability as predicted at the time of nomination. In practice such authorization may be of marginal value.

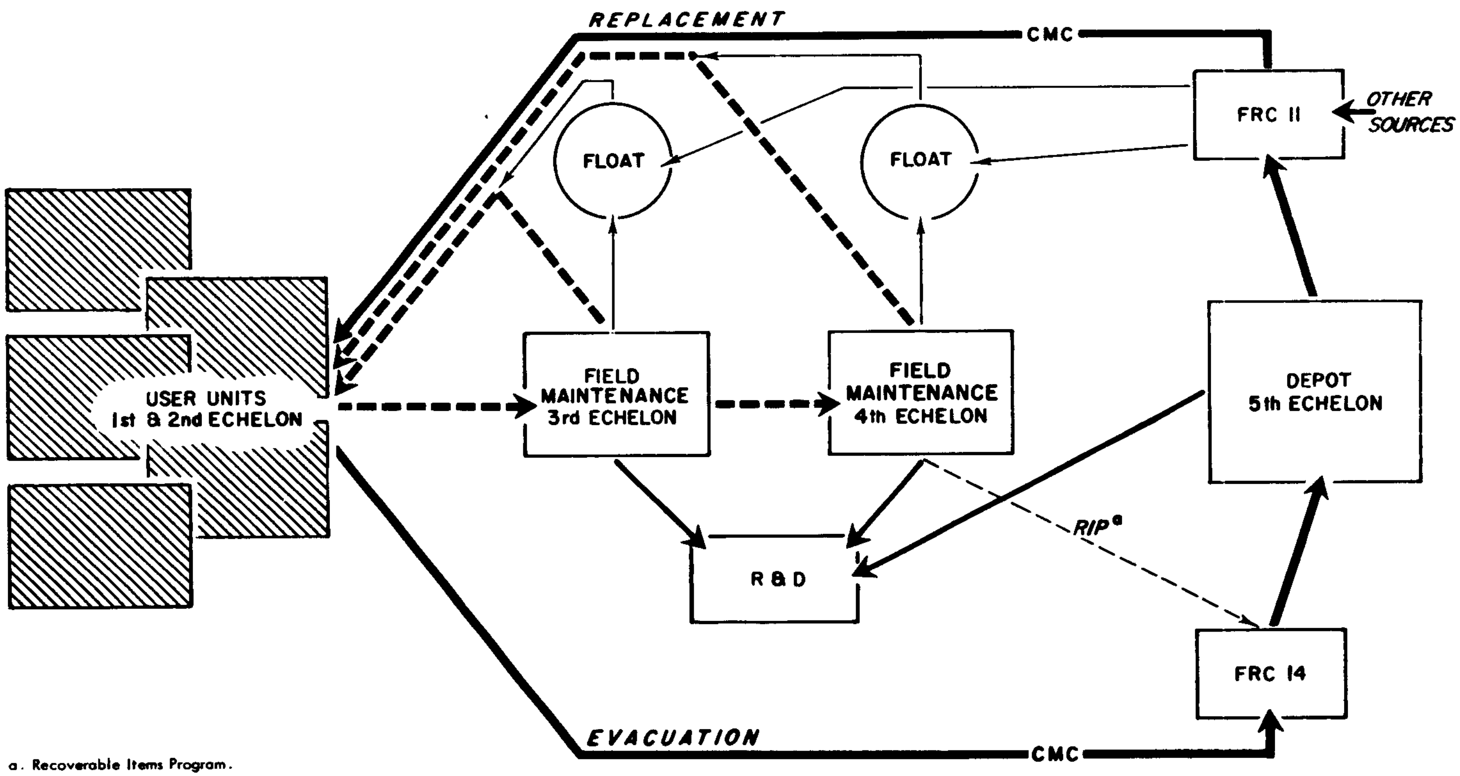
When a piece of equipment nominated is approved for replacement, in effect, it is scheduled for evacuation to rebuild. Good materiel management dictates that only the absolute minimum repair and maintenance expense be sunk in such equipment. Unit funds are thus conserved for wiser investment in equipment remaining in service and duplication of effort and expense at field and depot levels is avoided. The study team observed, especially in units with a heavy workload, a tendency to defer organic maintenance on equipment nominated for rotation in favor of equipment scheduled to remain in service. This tendency to defer maintenance, especially repairs, in equipment approved for rotation in R&E may tend to accelerate the unserviceability of the equipment scheduled in the program.

Figure 2 illustrates the relationships between the various echelons of maintenance in the current R&E Program. The flow of equipment between user units and field maintenance is indicated by the heavy broken lines. To avoid further complicating the example only one set of flow channels is shown. But since each unit has independent relations with its field maintenance support, in reality a separate set of heavy broken lines runs between each user unit and field maintenance.

The R&E cycle creates an entirely different relationship. The role of field maintenance echelons in R&E is essentially passive; they provide certain services but are removed from all management decisions. Essentially the relationship is that shown by the heavy solid line between 1st and 2nd Echelons and the 5th Echelon via CMC. The procedure for selecting the equipment is taken outside the usual maintenance pattern, up the echelons of command rather than the echelons of maintenance.

The annual R&E Program letter directs that only the poorest equipment be replaced and authorizes transfer between units in the same area if necessary to assure this is done. However, this is not always easy to accomplish. In our field interviews there was frequent allusion to the idea that R&E allocation was often conducted on a share and share alike basis among units. We doubt this to be wholly accurate. Nevertheless the selecting of the poorest equipment does present a problem.

Since replacement equipment usually arrives in several shipments spaced throughout the year, a really accurate determination of the poorest equipment would require several sets of detailed inspections--one set at each time a decision was made as to which individual items of equipment were to be replaced. Such inspections would be required on both the equipment originally nominated and on equipment which is unserviceable but not nominated because it did not meet the age/use criteria.



a. Recoverable Items Program.

SOURCE: NWRC, Stanford Research Institute.

FIG. 2 MAINTENANCE ECHELON RELATIONSHIPS UNDER CURRENT REPLACEMENT AND EVACUATION PROGRAM

The workload involved in a careful program of inspection might be excessive. For example, one Marine Division recently required that a limited technical inspection be performed on all communication electronics gear and although the task was given high priority, it required nine months to accomplish. Since only the most skilled technicians are qualified to perform inspections, heavy inspection programs cannot help but hinder maintenance performance by diverting key personnel from repair work.

Even if area commanders manage to select the poorest equipment, the problem is not solved. If equipment condition is affected by the area in which used, exchange of equipment between units in an area would only tend to equalize the condition of equipment in that geographic area and would neglect the real problem, that of assuring required materiel readiness. In an area hard on equipment, all equipment would tend to be more uniformly poor, regardless of the materiel readiness required of the units in the area. At the same time, in an area kinder to equipment, general materiel condition would be of a higher standard, even though the missions of the USMC units in the area required a lower condition of materiel readiness.

It is most important that only the poorest equipment is in fact replaced; for once a piece of equipment is evacuated, all service life remaining in it is lost to Fleet Marine Force and the Marine Corps until the equipment completes the 5th Echelon cycle and is again ready for issue. Any service life wasted by premature evacuation or administratively accelerated unserviceability deprives another area where the need may be greater since all replacements are issued from the common assets pool of the Marine Corps.

It is difficult to make a comparison of the absolute serviceability of equipment in widely separated units. However, since there are considerable differences in the various factors contributing to unserviceability, it is reasonable to expect different patterns of unserviceability in different units. Field observations by the study team substantiated this. Figure 5 provides an illustration.* Except in one case, the average annual parts costs for Third Division tactical vehicles are greater than those of the First Division. In fact in five of the eight cases shown, Third Division costs are twice as much as those of the First Division. In Figure 6 another comparison is presented.* Without

---

* Figures 5 and 6 are described in detail in Section IV where the relationship of age and use to equipment unserviceability is discussed.

respect to age of equipment, the Third Division percentage of vehicles deadlined is three or more times greater than the percentage of deadline vehicles in the First Division. The data compared in these two figures were for the entire population of this equipment in the six organizations shown. This suggests that the worst equipment in the First Division on mainland could be as good as or better than many pieces which will have to remain in service in Okinawa in the Third Division. There is no current procedure to prevent this. The current R&E Program hazards the evacuation of better equipment in some cases than that retained in FMF service.

A large volume of correspondence is required to conduct the R&E Program, even though it was conceived as an almost automatic system. For example, Headquarters, Fleet Marine Force Pacific, was addressee or originator on 157 official letters and 371 messages concerning R&E during FY60. In FY61, 74 letters and 312 messages required processing at FMFPAC to administer the program. At the same command, the file on R&E FMFPAC program FY59 containing a single copy of each official document was 6-1/2 inches thick. This tally of correspondence does not include any of the intradivisional or brigade correspondence required or the intrastaff memoranda required at any of the Fleet Marine Force Pacific commands or any of the supply documents produced. The program for FY59 was not closed until late spring of 1961. The FY60 and FY61 programs are still in operation at the time of writing of this report. The workload required to maintain this level of paper work is large and takes time which could be better devoted to more pressing problems of operational readiness.

Annually, cognizant Headquarters, USMC, staff personnel receive the nominations or requests from Fleet Marine Force Atlantic and Fleet Marine Force Pacific. They are then required to determine the numbers and types of equipment available for distribution in the program. The amount and type of equipment available for distribution through R&E is arrived at by projecting the serviceable asset (FRC 11) position of the Marine Corps through the program year. These calculations must take into consideration many factors, some of which are difficult to assess. Analysis of FRC 11 (serviceable assets ready for issue) must consider at least the following:

1. Assets already earmarked for distribution in an earlier R&E Program not yet completed

2. Expected changes in USMC units

3. Changes in tables of equipment for units already in operation

4. Predicted proceeds from the Master Work Schedules at the MCSC repair divisions

5. Equipment modernized through special project work orders

6. New procurements

7. Equipment available from interdepartmental purchases

8. Requirements for mobilization reserve

9. The Cloud and Storm program requirements

Once this analysis is complete, the annual replacement quota is based on what is available for distribution rather than on the stated needs of FMF. Perhaps the whole procedure of nomination is wasted. The stated desires of the Fleet Marine Force commands are only a maximum goal which the program administrators attempt to meet in the initial approved R&E quotas. Furthermore, if the original nominations are inaccurate and more replacements are required, the program administrator is faced with the problem of producing still more assets.

Much of the administrative complexity of the R&E Program stems from the original assumption that age/use criteria would be an excellent short-cut method of predicting some average condition of unserviceability at which equipment should be evacuated to rebuild. It was believed at the time that the equipment population would demonstrate small variability. This predictor (age/use criteria) was assumed to be so accurate that both the nominating and replacement procedures were based directly on the criteria.

In practice, the age/use criteria proved to be an inaccurate predictor of the future state of individual equipment. The equipment population showed great variability. Since actual replacement and the criteria were connected, various stopgap measures to inhibit premature evacuation were adopted. These measures complicated administration of the program. If an item of equipment is nominated either a replacement occurs (whether needed or not) or the nomination must be cancelled. The former alternative may cause premature evacuation of equipment. A large number of nomination cancellations, on the other hand, has the effect of creating administrative chaos on the system level.

The true goal of the nominating process, however, should not be to earmark actual equipment for rotation. It should be to provide a basis for over-all program management: planning for serviceable assets required and distribution on an area level.

Finally, the very nature of the R&E Program makes the analysis not only of its own contribution but of various improvements and changes in the greater materiel program difficult to evaluate. The effect of the program on materiel readiness is concealed. For example, a piece of equipment in R&E becomes truly unserviceable only upon the arrival of the piece of replacement equipment at the user unit. The effect of improvement in repair parts availability or other improvement in maintenance facilities on the readiness condition of the unit is lost because the old equipment for which the change is devised is evacuated and the new set of conditions is immediately created.

Attempts to assess the cost of the R&E Program to date have been unsuccessful for several reasons outside the scope of the R&E Program. First, with the possible exception of tracked vehicles, it is not possible to identify at the MCSC which equipment in the unserviceable assets pool actually came from the Fleet Marine Force under the R&E Program. It is not the practice at the supply center to segregate such materiel, and the equipment logs (which are not always available) do not always indicate the basis for evacuation. Second, the practice of writing block job orders for processing large numbers of equipment conceals the real cost of repairing individual equipment, even in instances where it is possible to identify the source of individual items. The only comparisons that can be made are between job order cost averages which give no indication of variability. Third, much of the materiel evacuated under R&E has not yet been repaired but rather is carried as FRC 14 (unserviceable assets awaiting repair). Thus, not even average actual cost to repair equipment is available because much of the equipment has not yet been converted to serviceable condition. Finally there have been major changes in repair methods during the period the R&E Program has been in operation and consequently comparisons of historical costs would be meaningless even if they were available.

Attempts to calculate the number of equipment items required to support various concepts for replacement and evacuation failed. It became apparent early in the study that the number of equipment items required to support replacement programing was more dependent on the time to cycle unserviceable assets through the Repair/Rebuild Program and into serviceable condition than on any other factor.

The time required to distribute replacement equipment to the FMF commands and to evacuate worn, unserviceable equipment back to rebuild is a small interval compared with the period actually required to cycle the equipment through repair/rebuild. For example, assume three months is required to ship replacement equipment from Barstow to Okinawa and a like period is required to evacuate unserviceable equipment back from Okinawa. If the entire shipment of equipment can be cycled through rebuild at Barstow in a six-month period, the inventory required to support the program in Okinawa would equal the inventory in use in Okinawa plus the number of equipment items programed for replacement annually. If, on the other hand, the rebuild cycle at Barstow is more than six months, the required inventory would equal the FMF-Okinawa in-use inventory plus two annual programs for replacement (that required for the replacement in the current program and that required for the next program.)

Further, if, as has been the usual case, Barstow is not only unable to cycle the unserviceables through rebuild within this time period but is also unable to rebuild the same amount of equipment as is included in the annual program, the inventory will be the previous figure plus the difference between that required and that which is rebuilt. Each failure at 5th Echelon to recycle equipment from unserviceable to serviceable condition either in the time frame of the program year or in numbers of equipment items in the program constitutes a net increase to the inventory count required to support replacement programing. The rate at which this deficit occurs can be lessened by distributing replacement equipment during the program year in several increments as production at the repair divisions is completed. However, the simple arithmetic of issuing more equipment than can be recycled to serviceable condition is irrefutable.

No criticism of the 5th Echelon is implied in these comments. What is intended is to illustrate the close relationship required between management of equipment replacement programing and the rebuild programing on which the replacement program is dependent for assets to issue.

The original R&E Program postulated an orderly cycle in which worn equipment would go from FMF, through rebuild, and into the serviceable assets pool, and would then be reissued to the Fleet Marine Force as replacement equipment. Thus each program was to provide the raw material for the other. Economically repairable worn equipment evacuated by R&E would be the unserviceable assets inducted for rebuild at 5th Echelon. Serviceable assets refurbished by the 5th Echelon Master Work Schedule would be the primary source of the annual replacement quotas of the R&E Program.

Because of this interdependence, one way to measure the effectiveness of the R&E Program is to observe what has happened at 5th Echelon. Where records are available, it is possible to compare the number of items of equipment rotated through R&E with the number of pieces of equipment rebuilt at 5th Echelon. If there is a reasonable balance between the two and there is a steady or declining inventory of unserviceable assets at 5th Echelon, one of the original missions of the R&E Program is being achieved, i.e. long-range materiel readiness is being insured. The opposite conditions are a warning that future materiel readiness may be impaired, and this is actually the case, to a greater or lesser degree, depending upon the type of equipment being considered.

Such comparisons must be handled with caution however. The implications to future materiel readiness of an imbalance between serviceable and unserviceable assets or equipment rotated and equipment rebuilt is clear. Explaining the deficits is not simple however. They may, on the one hand, be the fault of the R&E Program. On the other hand such deficits may be caused at 5th Echelon. Shortages of manpower, repair parts, and money, or inefficient repair processes at 5th Echelon could be among the explanations. Further causes occur at the management levels. Emphasis on activity other than rebuild at 5th Echelon (such as Supply Center support), lack of immediate requirement for the serviceable assets, a more pressing need for one type of serviceable assets than for another, or modernization programs are examples of situations requiring management decisions which could contribute to an imbalance between 5th Echelon rebuild and equipment replacement.

In the course of this investigation, it was observed that the increasing backlog of unserviceable assets at 5th Echelon was caused by all of the above, i.e., the R&E Program, the 5th Echelon Repair/Rebuild Program, and HQMC management decisions and processes. Regardless of why the 5th Echelon is not recovering serviceable assets at the same rate the R&E Program is generating unserviceables, it is important to measure the rate at which the deficit is occurring. Table IV affords the opportunity to do this. The end-items of equipment included in Column 1 are those selected by HQMC equipment specialists as mission essential or as the most important equipment types within the various classes of equipment. The quarterly R&E Program reports required of the Marine Corps Supply Center, Barstow, by the annual R&E Program letter were the source of the numbers of equipment shipped by MCSC Barstow to FMFPAC during FY59, 60, and 61. These are shown in Column 3. The Director of the Repair Division, MCSC Barstow, provided lists of all end-items of equipment completed on the Master Work Schedule (Project-59) for the same period. This equipment comprises Column 4. Column 5 shows the net difference between equipment issued by Barstow to the field and that rebuilt during the three-year period. Further data were obtained from an inventory of the Barstow FRC 14 account (unserviceable repairable assets) recorded in mid-calendar 1959 (no earlier reports were available at either Supply Center). On November 16, 1961, through an Exception Stock Status Report, the FRC 14 account for the Barstow complex was obtained (Columns 6 and 7).

Table IV

THE EFFECT OF REPLACEMENT AND EVACUATION ON 5TH ECHELON BACKLOG AT MCSC, BARSTOW Fiscal Years 1959, 1960, and 1961

Item	Fiscal Year	Shipped	Rebuilt	Net	FRC 14 1959	FRC 14 1961	FRC 11
Engineer equipment							
SN	1959	0	0				
	1960	0	0				
	1961	0	8				
Net				+8	--	11	11
M37	1959	0	0				
	1960	13	0				
	1961	6	0				
Net				-19	--	3	9
MS-10	1959	6	0				
	1960	3	0				
	1961	0	0				
Net				-9	--	33	83
TD-18A w/AD	1959	1	86				
	1960	33	0				
	1961	43	0				
Net				+9	--	7	18
TD-18A w/BD	1959	5					
	1960	6	0				
	1961	3	0				
Net				-14	--	1	86
TD-24 w/AD	1959	0	0				
	1960	4	0				
	1961	3	0				
Net				-7	--	22	6
Compressor, 105 cfm, TM	1959	7	0				
	1960	8	7				
	1961	8	0				
Net				-16	no data	no data	no data
Floodlight set, elec., TM	1959	7	0				
	1960	6	20				
	1961	6	0				
Net				+1	--	--	14
Generator set, diesel, 30 kw, TM	1959	7					
	1960	1					
	1961	1	0				
Net				-9	no data	no data	no data
Saw, radial, over arm, TM	1959	1	0				
	1960	1	0				
	1961	0	0				
Net				-2	--	1	--
Welding machine, TM	1959	2	0				
	1960	8	0				
	1961	0	0				
Net				-10	--	--	--

Table IV (continued)

Item	Fiscal Year	Shipped	Rebuilt	Net	FRC 14 1960	FRC 14 1961	FRC 11
Communication-electronics equipment							
AN/TGC-6	1959	0	3				
	1960	24	30				
	1961	0	0				
Net				+9	7	84	8
AN/GGC-3	1959	3	0				
	1960	3	6				
	1961	0	0				
Net				0	4	12	81
AN/PRC-6	1959	181	0				
	1960	251	0				
	1961	0	0				
Net				-432	369	340	2,384
AN/PRC-8	1959	7	0				
	1960	16	10				
	1961	0	0				
Net				-13	10	47	116
AN/PRC-9	1959	208	0				
	1960	89	0				
	1961	0	0				
Net				-297	--	--	--
AN/PRC-10 series	1959	194	0				
	1960	268	0				
	1961	0	0				
Net				-462			
AN/PRC-10					168	589	32
AN/PRC-10A					27	28	--
AN/GRC-9 series	1959	104	2				
	1960	57	0				
	1961	0	0				
Net				-159			
AN/GRC-9 group					--	--	8
AN/GRC-9Z					30	2	50
AN/MRC-37	1959	14	0				
	1960	35	46				
	1961	9	0				
Net				-12	--	94	20
AN/MRC-38	1959	15	0				
	1960	11	28				
	1961	1	0				
Net				-29	16	65	25
AN/MRC-62	1959	6	0				
	1960	8	0				
	1961	6	0				
Net				-20	--	17	--
AN/TCC-11	1959	8	0				
	1960	15	0				
	1961	1	16				
Net				-11	9	37	82

Table IV (continued)

Item	Fiscal Year	Shipped	Rebuilt	Net	FRC 14 1960	FRC 14 1961	FRC 11
Motor transport equipment							
M35	1959	306	0				
	1960	173	0				
	1961	170	0				
Net				-649	75	800	200
M38A1	1959	326	196				
	1960	407	277				
	1961	64	330				
Net				-14	378	661	405
M49	1959	28	0				
	1960	8	34				
	1961	13	0				
Net				-15	10	96	--
M51	1959	40	0				
	1960	39	40				
	1961	53	0				
Net				-92	23	146	12
M52	1959	13	0				
	1960	11	0				
	1961	10	0				
Net				-34	4	29	82
M54	1959	136	126				
	1960	0	0				
	1961	0	0				
Net				±0	92	97	10
M62	1959	19	0				
	1960	0	6				
	1961	4	0				
Net				-17	7	10	--
M100	1959	202	0				
	1960	250	0				
	1961	0	0				
Net				-452	178	778	177
Trailer, greasing	1959	37	25				
	1960	34	45				
	1961	0	15				
Net				+14			no data
Trailer, NPCU	1959	39	0				
	1960	19	0				
	1961	0	0				
Net				-49	--	77	4

Table IV (concluded)

Item	Fiscal Year	Shipped	Rebuilt	Net	FRC 14 1959	FRC 14 1961	FRC 11
Ordnance equipment							
M53	1959	4	0				
	1960	1	0				
	1961	1	0				
Net				-6	10	18	2
M55	1959	0	0				
	1960	2	0				
	1961	6	0				
Net				-8	1	14	--
LVTP5	1959	27	0				
	1960	53	51				
	1961	44	0				
Net				-73	58	176	161
M48 A1	1959	0	10				
	1960	27	0				
	1961	18	0				
Net				-35	0	78	23
M50	1959	13	2				
	1960	32	0				
	1961	2	0				
Net				-45	7	71	18
M67	1959	2	0				
	1960	2	0				
	1961	0	0				
Net				-4	6	18	6

Source. Repair and Materiel Division records, USMCSC, Barstow, California.

For Official Use Only

In many cases there is considerable discrepancy between the deficit directly chargeable to the R&E Program and the change in asset positions recorded between 1959 and 1961. However, the R&E Program did issue many types of serviceable assets at a greater rate than the Marine Corps 5th Echelon Program recovered them. The final column of Table IV lists the Barstow inventory of FRC 11 (serviceable assets available for issue) for the November 1961 report.

IV STANDARDS AND DEFINITIONS OF UNSERVICEABILITY

Introduction

Age (whether in storage or service) and use (such as miles traveled or hours operated) are the means by which service life of equipment is expended. The net rate of this expenditure is affected by other factors such as maintenance and repair facilities, environment, unit operating conditions, and command policy.

Maintenance facilities restore service life used up in equipment through timely, adequate repairs. They should include proper repair parts available at the proper place at the proper time; adequate maintenance personnel, including experienced management and sufficiently skilled technicians and helpers; proper repair tools and equipment; and adequate shop space for efficient working conditions (this may be only a van or tent in bivouac).

Equipment goes into maintenance for repair of some substandard condition. If maintenance facilities are efficient, not only is that specific condition corrected, but others are anticipated. Early in the life of equipment, postrepair condition may be even better than new condition as manufacturing flaws may be corrected. However, as the equipment ages in time and use, even the most efficient repairs cannot be expected to restore full service life. Even so, timely and proper repairs will greatly extend equipment serviceability. Conversely, inadequate repairs sometimes hasten the arrival of unserviceability more than age or usage.

Terrain, temperature, humidity, and the other factors of the physical environment greatly affect the deterioration of equipment.

Among the unit operating conditions which affect equipment service life are: frequency, tempo, and duration of training maneuvers, the skill of equipment operators, the availability of time and personnel for organic preventive maintenance, and whether unit exercise areas require frequent shipboard loading and off-loading, whether the equipment is used only for training. (Use of tactical vehicles for administrative transport and of reefers on field maneuvers only are two negative examples. One uses the equipment too much, the other too little, for optimum serviceability of the equipment.)

Command can affect equipment serviceability in two broad areas: definition and practice. Although the words "serviceable" and "unserviceable" are usually only comparative terms, there is a tendency to use them as if they were absolutes. There are differing command definitions of what constitutes an unserviceable condition, and some are a function of the command status. What might be serviceable in a unit with a low readiness requirement might be unserviceable in another unit which had to be ready to mount out on short notice. Other command definitions of serviceability are a function of the unit commander's interpretation of the relative importance of various matters.

For example, in field interviews the study team learned that the tactical commander often has a different viewpoint than the logistician of what materiel readiness is. Not "What is the condition of materiel?" but "How does the materiel condition affect the unit mission?" While this is the proper emphasis, it does cause multiple standards of serviceability. A commander of a unit in which equipment makes only a secondary contribution to the unit mission, or in which there are alternative means of performing the task, might establish standards of serviceability much lower than those established by a commander for whom such equipment is essential to mission performance. Command practice regarding such factors as operator training and organic maintenance, both preventive and repair, are also important determinants of equipment condition. In a unit where the commander takes strong interest in equipment use and maintenance, high serviceability usually results.

This study began with the idea that its main contribution might be a more accurate set of age/use criteria for each equipment type. Then it became apparent that there would be little meaning to a single set of criteria. There were too many different ways and different places in which service life was being used up in Marine Corps equipment.

Marine Corps equipment is operated in many locales, and a given piece of equipment may be used within the same locale in different ways. An example is the TD-18 tractor. The TD-18 family of tractors is used by Force Service Regiments as a prime mover in a beach environment. It is used in the Pioneer Battalion as heavy construction equipment. It is also used in the artillery regiments as a prime mover and revetment digger. Each of these uses generates a different tempo of employment and a different degree of experience in the operator, has a different amount of backup of organic maintenance, and occupies a different position of importance in the viewpoint of the unit commander. The Engineer-Pioneer organization, for example, considers the tractor to be a fundamental mission-essential, whereas the artillery commander may think of it primarily as one means of conveying his mission-essential equipment; except in exercises, the FSR commander may never even consider the equipment.

Not only is service life being taken out of the equipment differently, service life is being restored to equipment differently, depending upon the particular maintenance situation at each Marine Corps installation. This varies from organization to organization, and within a given organization, varies from time to time. Because of the variety of factors contributing to the unserviceable condition of equipment, it is apparent that the unserviceability of equipment cannot be predicted on the basis of age/use criteria alone.

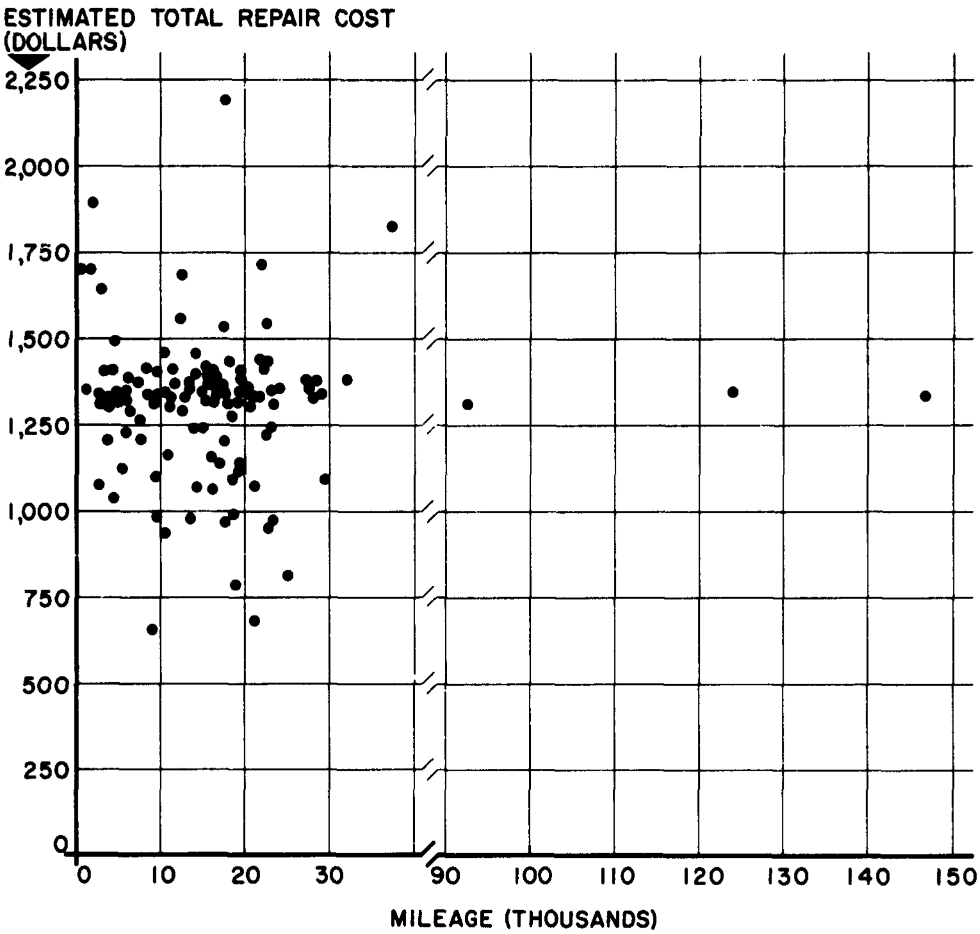
Age/Use Criteria

Since its inception, the R&E Program has been equipment oriented and based on age/use. There is one criterion for a given type of equipment--wherever, however, by whomever it is used--which makes that equipment eligible for R&E nomination. Since age and use are so fundamental to the program, it is important to examine the relationship of these contributors to unserviceability.

The five broad types of Marine Corps equipment are: ordinance, tactical vehicles, engineer, communication/electronics, and general supply. Each type has a different record-log format. Of these, the present communication/electronics logs are the most recently adopted. These records did not provide information sufficient either in time period covered or detail logged to permit analysis. General supply equipment was dropped early from R&E programing as being inappropriate for age/use criteria scheduling. Therefore, no analysis was made of these two equipment families.

In the ordnance group, the LVTP5 was selected for intensive study because this equipment is a Marine Corps peculiar item. Its operation is so vital to the USMC mission that it is almost a trademark of the FMF. Various USMC ordnance specialists recommended that emphasis be placed on analysis of tracked vehicles since peacetime use of artillery is too slight to give age/use analysis meaningful results.

Copies were obtained of the limited technical inspection (LTI) forms for the M35 trucks on which letters of unserviceability were issued from the Camp LeJeune area for FY60 and most of FY61. The scattergram in Figure 3 presents the estimated cost to repair each M35, plotted against the mileage in thousands of miles at the time of evacuation. (Note that



SOURCE: Limited Technical Inspection forms of 2nd FSR.

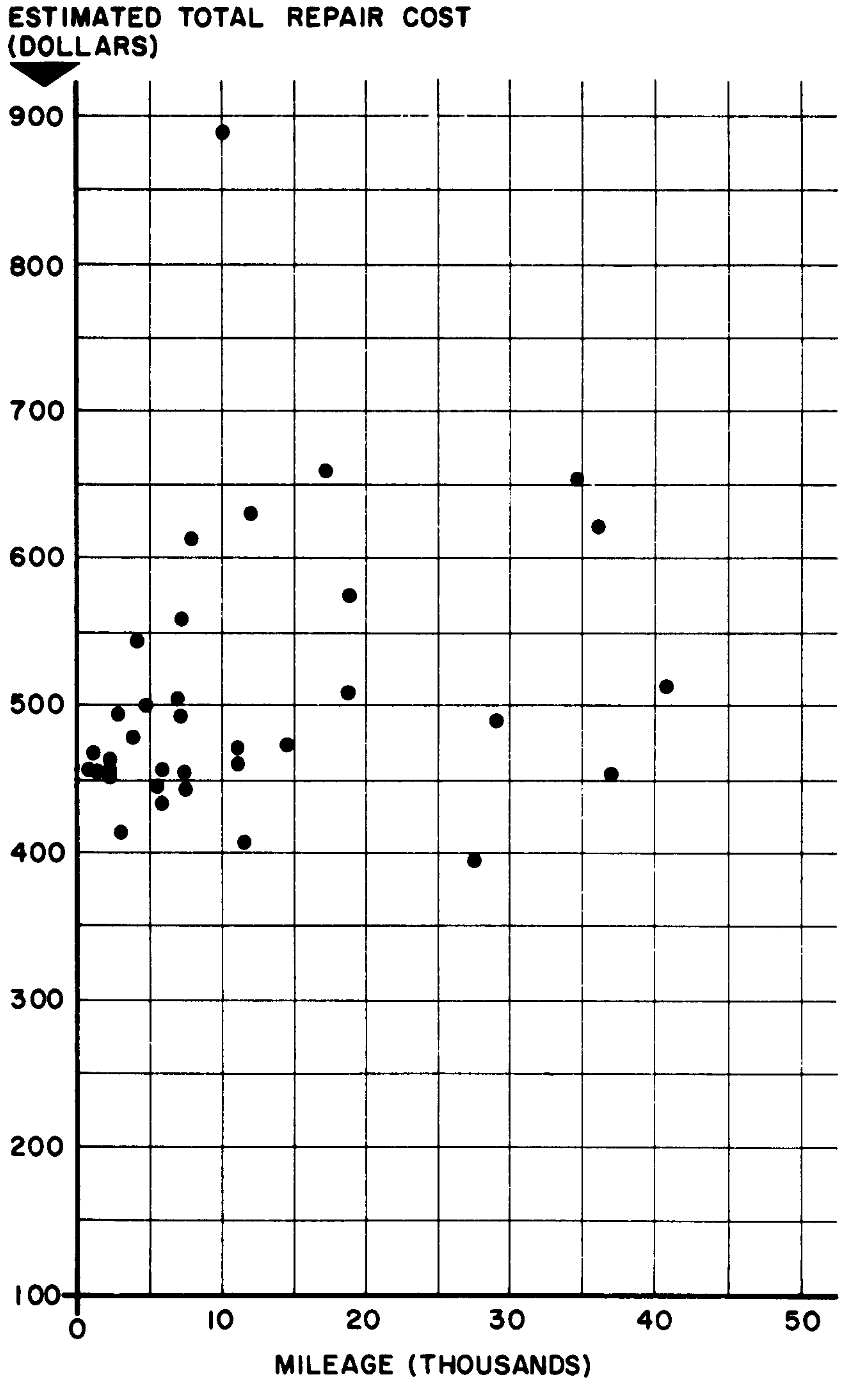
FIG. 3 ESTIMATED TOTAL REPAIR COST vs. MILEAGE FOR M-35 TRUCKS the chart is interrupted between 40,000 and 90,000 miles.) Each dot represents one truck. Some comments will be directed toward the LTI procedure later in this study. Regardless of how accurate the basis for individual estimates presented here may be, they were made at the same place under the same conditions. Whatever bias the estimates contain should be fairly constant and the estimates should describe relative conditions of unserviceability between the vehicles. This chart indicates little relationship between the use of these vehicles and one measure of unserviceability. The coefficient of linear correlation for this chart was 0.03 for the 114 events plotted.

Figure 4 is a similar plot for M38A1 jeep data obtained from the same source. This scattergram indicates a closer relationship between this same measure of unserviceability and use than that used for the M35. However, regression analysis produced a coefficient of linear correlation of only 0.23 (where N = 35). This indicates there is little casual relationship between this measure of use and the estimated cost of repair.

In mid-1961, Headquarters, Marine Corps (Code A04H), the Motor Transport Section of G4, requested for the purpose of budget calculation that six major FMF ground commands report information on their recent experience with motor transport. Figures 5 and 6 are based on these data. Figure 5 is a comparison of the average annual parts cost with average in-use age of eight types of tactical motor transport. Each of the six major FMF commands is indicated by a different symbol. No clear pattern of relationship between this measure of unserviceability (annual parts cost) and this measure of age (average in-use) are apparent in the individual charts. In the two charts comparing different configurations of the M38A1 the oldest vehicles are both the most expensive in average annual parts cost and the least expensive.

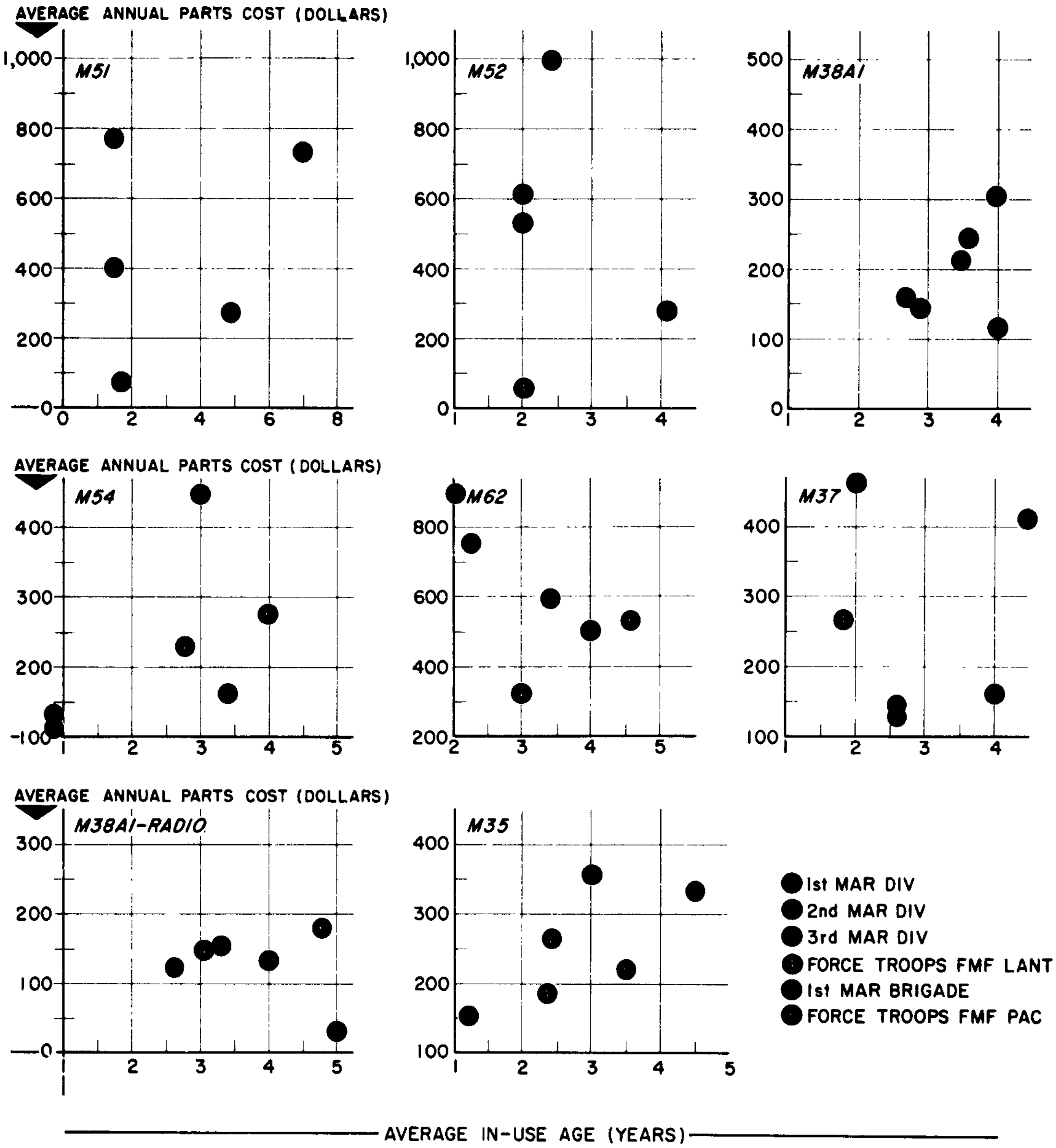
Parts costs appear to be more unit-connected than they are age-dependent. In five of the charts the annual parts cost of the 3rd Division are higher than for any other unit. This is true in the case of the M62 even though the average age of the 3rd Division M62 is the least of those presented. In the chart on the M38A1 jeep, the 3rd Division costs again are highest, although the vehicles have oldest average age. In the chart on the M35, the 3rd Division vehicles are roughly at the median point in age, but are highest in cost to repair.

Figure 6 is a series of comparisons of another measure of unserviceability with age. Average percent of tactical vehicles deadlined is compared with average in-use age of the equipment of the major FMF ground commands. The same eight vehicle types are presented. The vertical measure is percent of average deadline in the units; the horizontal



SOURCE: Limited Technical Inspection forms of 2nd FSR.

FIG. 4 ESTIMATED TOTAL REPAIR COST vs. MILEAGE FOR M38A1 JEEP



SOURCE: HQMC (Code A04H) records

FIG. 5 AVERAGE ANNUAL PARTS COST vs. AVERAGE IN-USE AGE FOR EIGHT TACTICAL VEHICLE TYPES

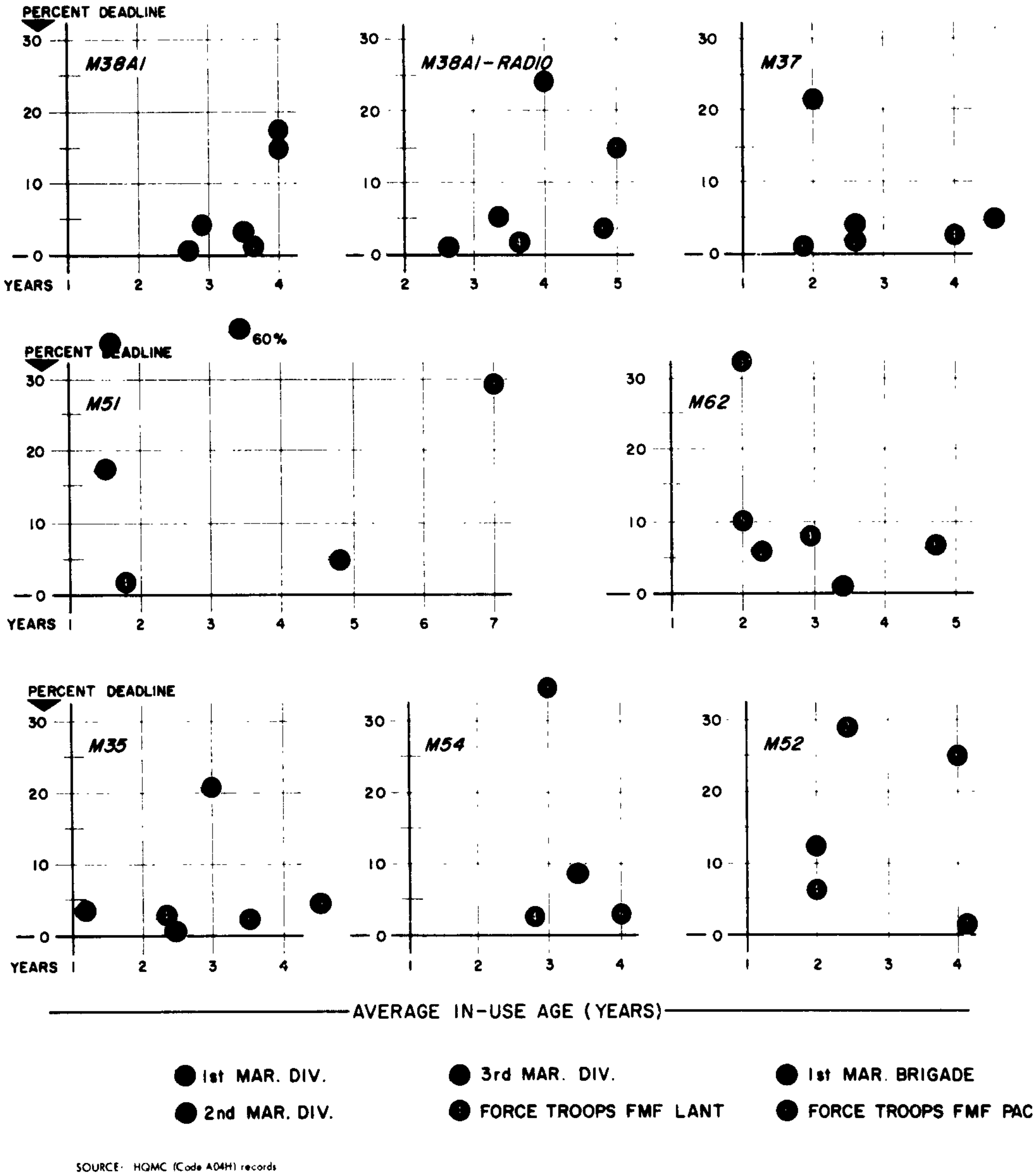


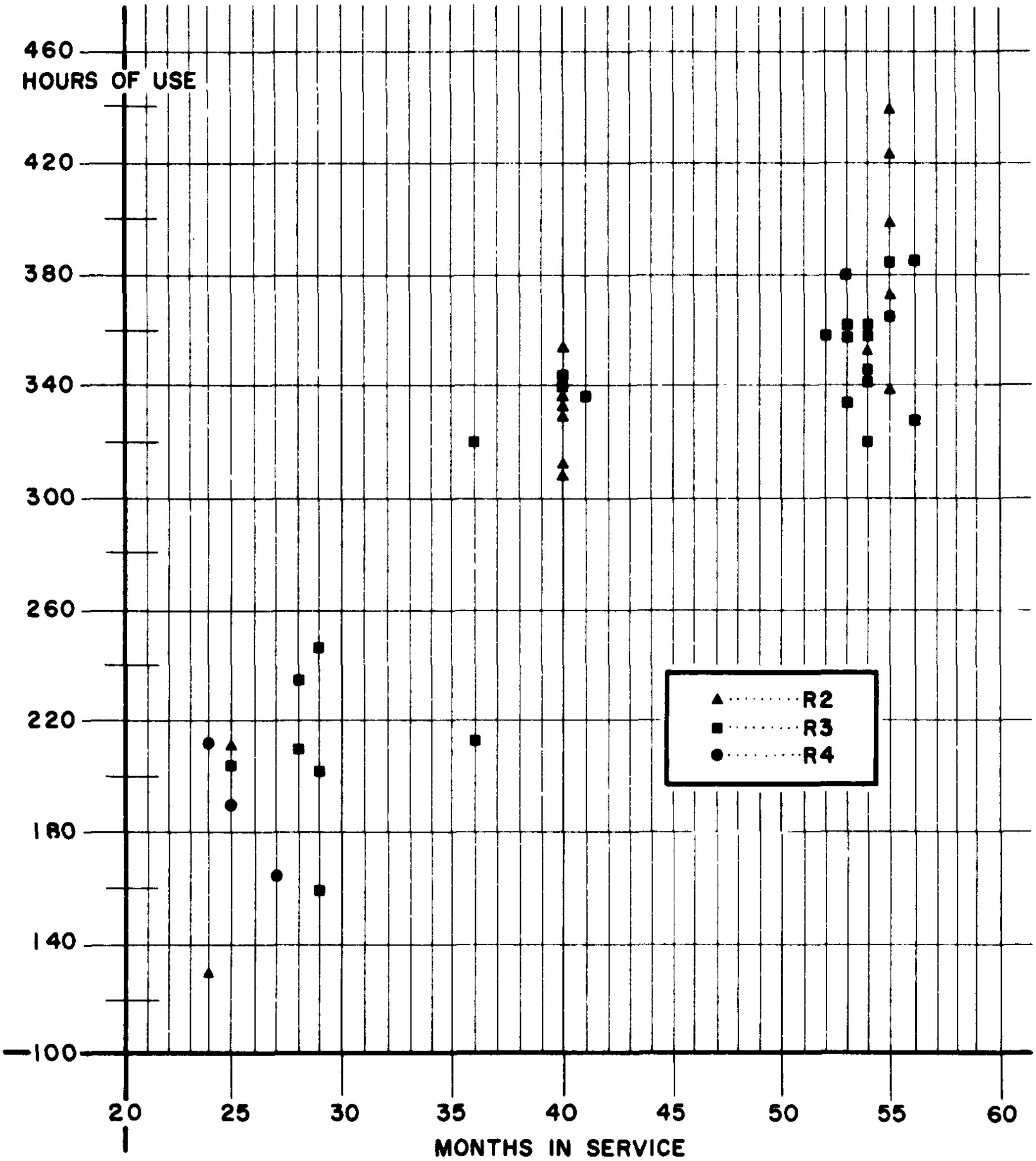
FIG. 6 AVERAGE PERCENT DEADLINE vs. AVERAGE IN-USE AGE FOR EIGHT TACTICAL VEHICLE TYPES

scale indicates average in-use age of the equipment, a symbol identifies the command throughout the series. The chart for the M38A1 indicates a fair relationship between unserviceability and age. However, none of the charts for other major types of tactical vehicles show a significant age-unserviceability relationship. There appears to be a much more consistent relationship in Figure 6 between the deadline and the parent organization--for example, the 3rd Division--than between deadline and age.

Another type of equipment, one basic to Marine Corps operations, is the LVTP5, the amphibious tractor. Figures 7 and 8 present the results of our analysis of tracked vehicle logs obtained at the Marine Corps Supply Center, Barstow. The condition codes shown in these figures are described in Table V. Of all tracked vehicle logs available at Barstow, those which were obviously incomplete were eliminated from consideration, as were those which indicated the LVTP5 had been sunk or wrecked, and those which were obviously inaccurate. For example, if the log showed many gallons of fuel consumed and little or no hours of operation logged, it was not used. Only 42 of the tracked vehicle logs located survived these tests. Of the 42, 14 were condition coded R-2, about 33 percent of the sample; 25 were coded R-3, about 59 percent of the sample; and 3 were coded R-4, 7 percent of the sample. The Records Section at Barstow had condition codes on 82 LVTP5's including these 42. Of these 82, 21 had been condition coded R-2, about 26 percent; 55 were coded R-3, 67 percent; and 6 were R-4, 7 percent. Thus the sample studied is generally representative of the condition at evacuation of those LVTP5's received at the Marine Corps Supply Center, Barstow. Relative condition of unserviceability should be fairly accurate.

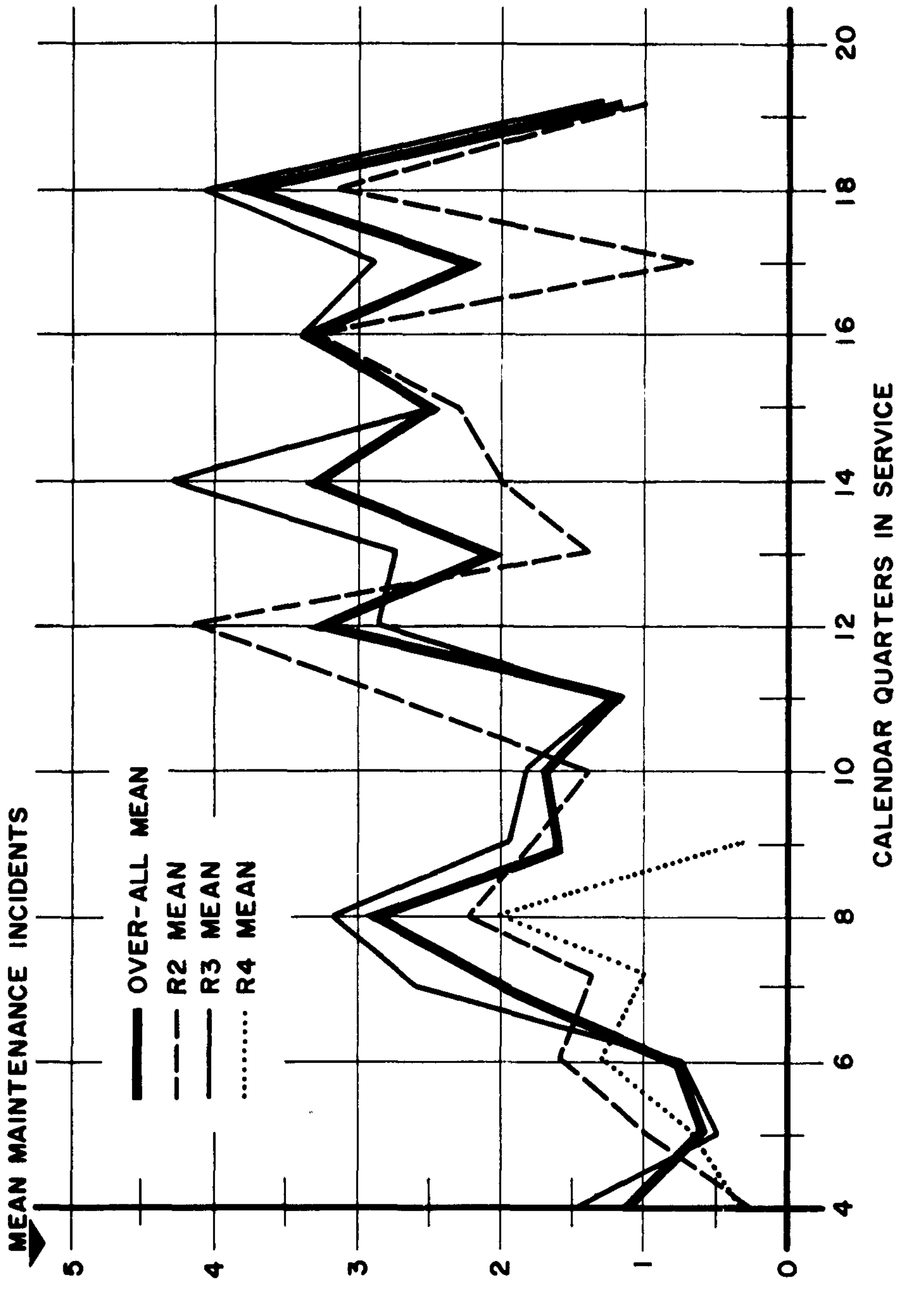
Figure 7 presents the condition and evacuation of those LVTP5's whose logs survived these tests. The vertical axis shows total hours of operations logged, and the horizontal axis shows total months in service. The figure contains the condition code assigned by the Barstow inspector. This figure indicates there is good relationship between the hours operated (or use) and months in service (or age). If a good relationship between unserviceability and either use or age were shown by the figure, the following general pattern would be expected: the R-2's would cluster in the lower left-hand corner; the R-3's would group toward the center of the chart; one would expect the R-4's to appear toward the upper right-hand area of the chart.

Instead of this predicted pattern, the actual plot appears to be almost reversed. All of the worst, the R-4's, are grouped with the youngest in age and hours. Those least unserviceable, the R-2's, extend throughout the whole scale and are in fact those with most



SOURCE: Tracked vehicle logs at MCSC, Barstow, California.

FIG. 7 CONDITION AT EVACUATION OF SELECTED LVTP-5 vs. HOURS OF USE AND MONTHS IN SERVICE



SOURCE: Tracked vehicle logs at MCSC, Barstow, California.

FIG. 8 MEAN MAINTENANCE INCIDENCE PER QUARTER IN SERVICE FOR LVTP-5

Table V

DEFINITIONS OF CONDITION CODES

Condition Code	Definition
R-1	Used property, still in excellent condition, but minor repairs required (repairs would cost not more than 10% of acquisition cost).
R-2	Used property in good condition, but considerable repairs required; estimated cost of repairs would be from 11% to 25% of acquisition cost.
R-3	Used property in fair condition, but extensive repairs required; estimated repair costs would be from 26% to 40% of acquisition cost.
R-4	Used property in poor condition and requiring major repairs; badly worn and would still be in doubtful condition of dependability and uneconomical in use if repaired; estimated repair costs between 41% to 65% of acquisition cost.
X	Salvage; personal property that has some value in excess of its basic material content but which is in such condition that it has no reasonable prospect of use for any purpose as a unit (either by the holding or any other federal agency) and its repair or rehabilitation for use as a unit (either by the holding or any other federal agency) is clearly impracticable; repairs or rehabilitation estimated to cost in excess of 65% of acquisition cost would be considered clearly impracticable for purposes of this definition.

Note: If the rules are followed strictly as written an anomaly occurs. There is a 1% gap between the upper limit of a condition code and the lower limit of the next successive code. For example, in the M35 (cost $6,800.00) Code R1, upper limit is $680; the lower limit of Code R2 is $748. Then repairs estimating $700.00 are not in either code. The intent of the order, however, is clear, and in all calculations used in this study, this intent was followed. The succeeding condition code begins at the upper limit of the next lower code; for example, M35 repairs costing $680 are Code R1; repairs estimated at $681 are treated as Code R2.

Source: The Marine Corps order P4400.20, the Marine Corps Supply Manual, Volume 2, Paragraph 205106, pp. 5-23..

hours of service. The R-3's, moderately unserviceable, appear in the earliest range of the chart and are distributed throughout.

Each of the LVTP5's shown in Figure 7 was evacuated under R&E. By the most generous criteria ever allowed in the program, only those with more than four years of service or 400 hours of operation met the age/ use standard for nomination eligibility. None of the LVTP5's on the figure met the current criteria of six years or 600 hours.

Additional measurements were made of these tracked vehicles. Figure 8 shows average incidence of maintenance per quarter in operation vs calendar quarters in service. An understanding of the data collection method is important to interpretation. From the 42 tracked vehicle logs which met the earlier tests described, we eliminated from the maintenance record such repairs as could be connected to accidental damage and those of a strictly service or incidental nature, such as battery changes and light replacements. Where repeated work of a similar nature was performed on the same component or system within a few days, all but the original repair was eliminated on the premise that the repetition indicated an incomplete or improper repair the first time. All remaining repairs were then aggregated for analysis without respect to echelon where performed or number of separate repairs performed simultaneously. If six components were repaired in one deadline, six repairs were counted. This was done for two reasons. It was almost impossible to interpret from the maintenance record by simple echelon coding the severity of the casualty repaired. Further, the number of repairs performed simultaneously may well have been a function of the availability of the LVTP5 for repair or of the availability of repair facilities at a given time. Repairs were aggregated by quarters because it was assumed that neither operational commitments nor inadequate repair space was likely to defer needed repairs longer than a quarter.

In Figure 8 the "mean maintenance incidence" is measured vertically and "calendar quarters in service" is measured horizontally. The heavy line represents the average for all LVTP5's analyzed. While there is an increasing incidence of maintenance as age increases, there is some doubt as to whether the absolute values represented are really significant. For example, for the three years of service between the 6th and 18th quarters, the repair rate for the over-all average increased on the average of one component repair per month, without regard for the size or severity of the repair indicated. The other lines in Figure 8 indicate the incidence of repair of those LVTP5's which were condition coded similarly at evacuation, and repairs are averaged each calendar quarter for each group. Each has a different history, and no clear pattern of interrelationships is developed. Variability from quarter to quarter tends to negate any trend.

It might be theorized that the lack of relationship between age/use and condition at evacuation could be explained by difference in emphasis on repairs and on component replacements during the service life of the individual equipment. In other words, perhaps an R-4 LVTP5 was in poorer condition at evacuation because it had received fewer of the needed repairs or replacement components during service life than one of similar age/use coded R-2.

To test this hypothesis, the incidence of repair per quarter was examined for individual tractors over the service life of the equipment. Differences in absolute values were not significant (see Table VI). The over-all mean for all LVTP5's was 1.9 per quarter. Those coded R-4 averaged 1.1 repairs per quarter; averages for individual equipment ranged from 0.6 to 1.7 in this class. Those coded R-3 averaged 2 repairs per quarter; individual items ranged from 0.6 to 4.3 repairs per quarter. The mean for LVTP5's coded R-2 was 1.8 repairs each quarter; the extremes in the group were 0.8 and 2.9 each quarter. Table VI also shows that the differences in numbers of major serialized components replaced during the service life of the equipment offered no explanation of the lack of correlation between age/use and condition at evacuation.

Table VI

REPAIR INCIDENCE AND SERIALIZED COMPONENT REPLACEMENTS FOR SELECTED LVTP5's

Condition Code	Number	Repairs per Quarter[a]			Serialized Components Replaced		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
R-4	3	0.6	1.7	1.1	0	4	2.
R-3	25	.6	4.3	2.	0	6	2.
R-2	14	.8	2.9	1.8	0	7	2.5
All	42	0.6	4.3	1.9	0	7	2.1

a. Averaged for service life of individual LVTP5.

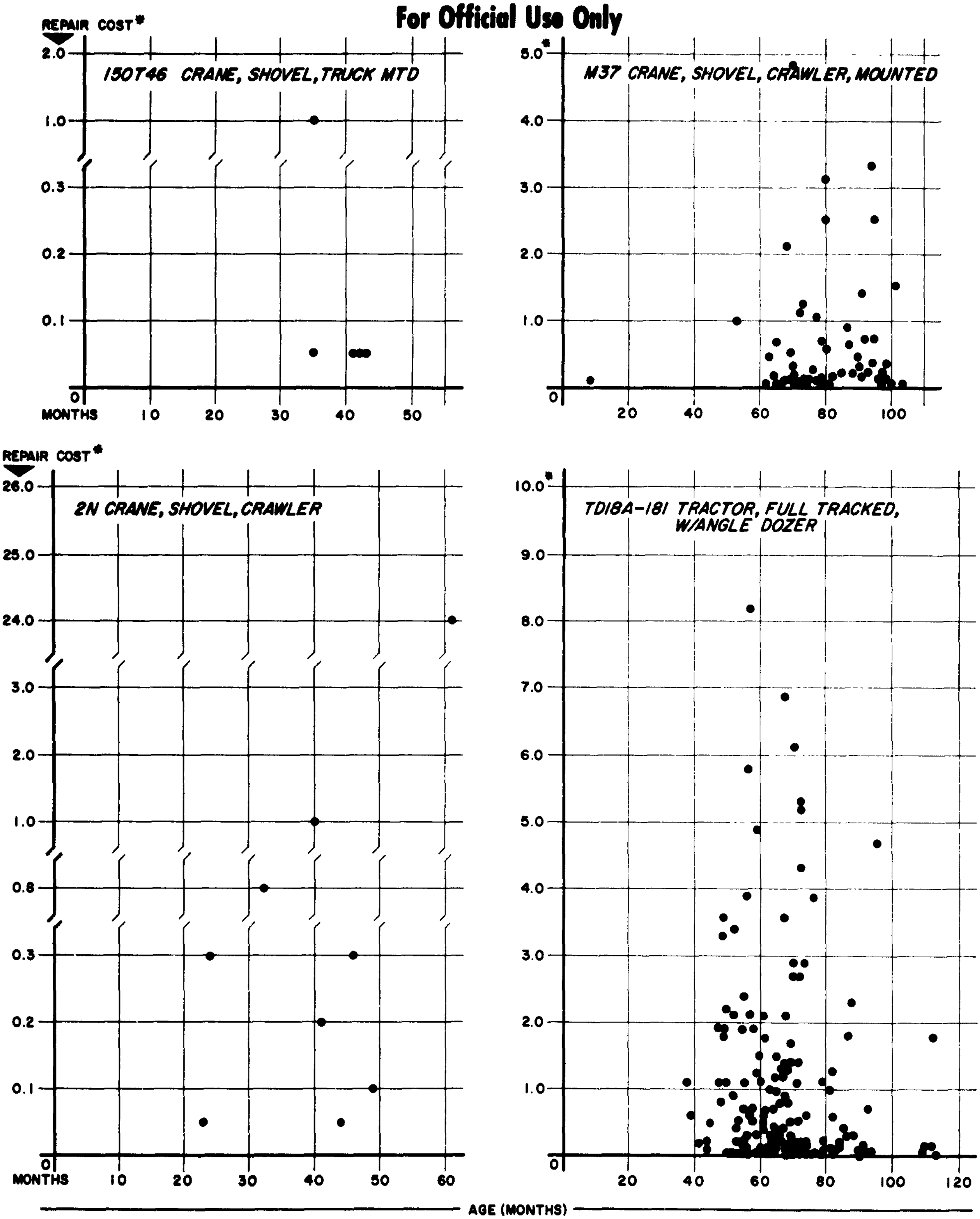
Source: Tracked Vehicle Logs at MCSC, Barstow, California.

Serialized component replacements for the equipment analyzed varied from no replacements to 7. The over-all mean was 2.1. R-4 tractors had from no replacements to 4 and averaged 2 serialized components exchanged. R-3 tractors had from no replacements to 6, and averaged 2 components exchanged. R-2 tractors varied from 0 to 7 replacements and averaged 2.5 component exchanges prior to evacuation.

In summary, equipment items coded R-4 and R-3 have slightly fewer component replacements than R-2's. On the other hand, those coded R-4 and R-2 have fewer repairs per quarter than R-3's.

Copies of the engineer item age and cost record (NAVMC10332-SD) were obtained from the First Pioneer Battalion and Marine Corps Supply Center, Barstow, for all equipment records held on the following equipment: the TD-18 family tractor/crawler, the Model 2N crane shovel/crawler, the 150P46 truck-mounted crane shovel, and the Bay City M37 crane shovel/crawler. From these records all of the estimated accumulated repair costs were eliminated which were entered in accordance with Marine Corps order 4710.2 enclosure (5) (these estimates were arrived at purely as a function of the age of the equipment and without regard to actual repairs performed). The remaining repair costs shown on the repair cost record were then reduced to a percentage function of the acquisition cost of the equipment. The reason for reducing cost of repairs to percentages of acquisition cost was to permit valid comparison of several types of equipment on a common scale. Some of these repairs were performed at 5th Echelon, others in the field.

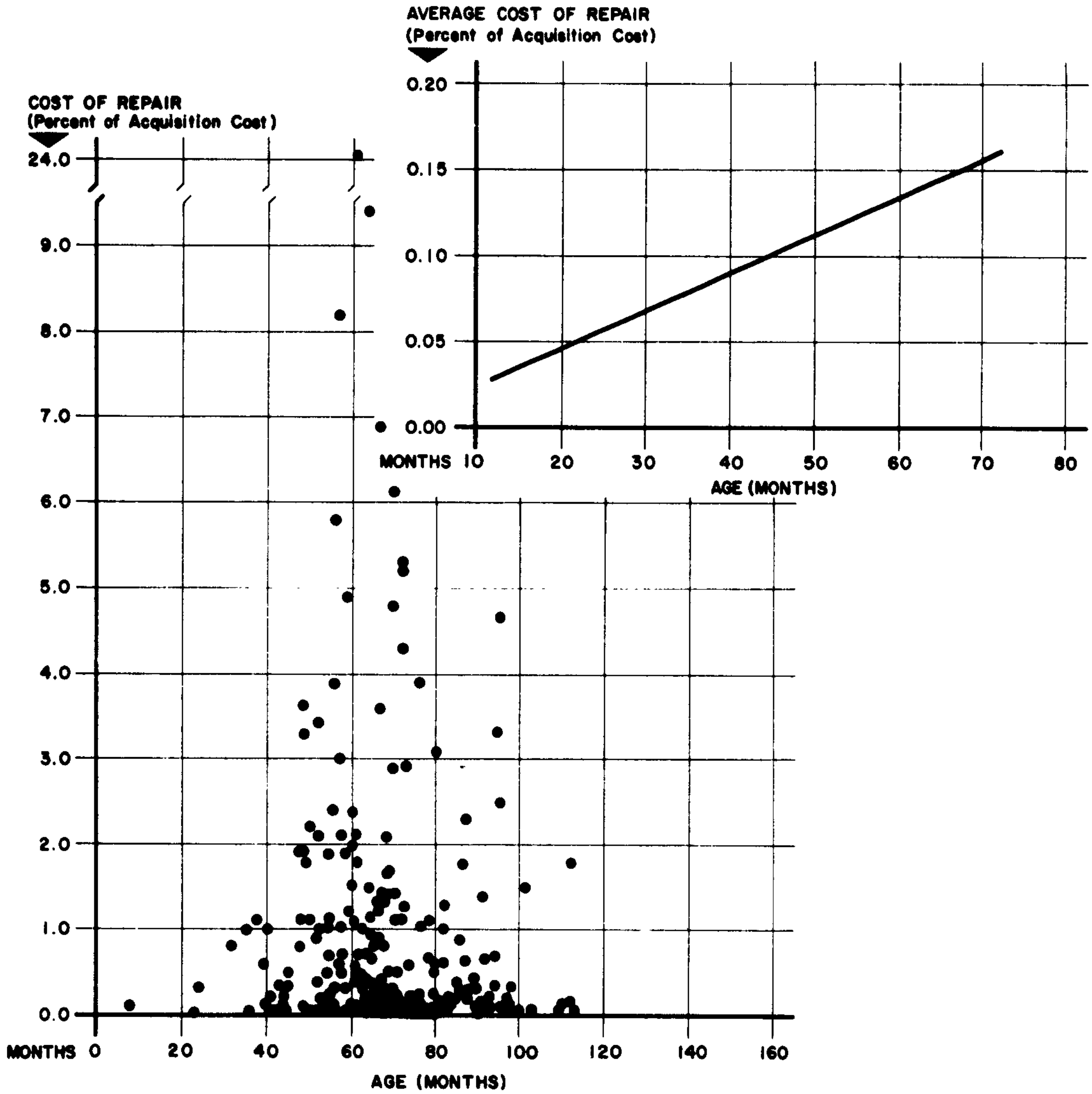
The charts shown in Figure 9 compare these costs of repair with the age of the equipment in months. The individual charts indicate small relationship between the cost to repair pieces of equipment and age of the equipment. However, Figure 10 aggregates the cost to repair all engineer items studied. When the data presented in Figure 10 were subjected to regression analysis, the linear coefficient derived was 0.396 for the 264 items plotted. This indicates a good causal relationship between this measure of unserviceability and age of equipment in months. The inset in Figure 10 plots the average cost of repair (in terms of percent of acquisition cost) versus age of equipment in months from the 12th through the 72nd month to illustrate the relationship between unserviceability and age in these items of engineer equipment. When the value of the cost of repair is considered in absolute terms, the significance of this relationship as a key to equipment replacement programing becomes questionable. As an example, consider the average monthly cost to repair the TD-18-181 tractor/crawler at 12 and 72 months. The increase of the average monthly repair cost at the end of the first year from $3.65



* Repair cost expressed as percentage of acquisition cost.

SOURCE: NWRC, Stanford Research Institute.

FIG. 9 REPAIR COST vs. AGE FOR FOUR ENGINEER EQUIPMENT TYPES



SOURCE: NWRC, Stanford Research Institute.

FIG. 10 SUMMARY PLOT OF REPAIR COST vs. AGE FOR ENGINEER EQUIPMENT to the average monthly cost to repair of $20.29 at the end of six years' operation is statistically significant. Whether the dollar value of such repairs would cause the decision to replace a $12,600 piece of equipment is another matter.

As a result of these analyses and numerous field interviews and observations of equipment in FMF and the MCSC, we conclude that age/use criteria are inaccurate predictors of unserviceability for FMF equipment. It appears that how, where, and by whom the equipment is used, and under what conditions it is used and maintained make a great contribution to the condition of equipment. It is not being suggested that age and use are unimportant contributors to unserviceability. Rather, that age and use used exclusively are poor predictors of the future state of unserviceability of an individual item of equipment. This is important to evaluating the R&E Program because the R&E organizing principle says in effect: If you will tell me how old something is or how much it is used, I will tell you when that item should be replaced.

Neither is it suggested that in a test-to-destruction that age and use would not be important in predicting ultimate or absolute unserviceability. However, this would be a pure academic exercise. There is no test available now, nor would one make sense if made. The Fleet Marine Force does not intentionally run unit equipment to destruction. What happens to a piece of Marine Corps equipment in service is roughly this: the piece of equipment is put into service and after some use arrives at some substandard state of performance. It then goes into maintenance for repairs. There, serviceability is restored (at least partially) and the equipment then returns to use. It is operated until it again arrives at some substandard condition and again repairs are performed. This same procedure is repeated throughout the time the equipment is in use. Thus the service life of a piece of FMF equipment is regenerated periodically. With each regeneration, the effect of previous age and use on equipment unserviceability is changed.

Condition Codes

A common set of standards and definitions of unserviceability meaningful at all echelons of command and maintenance is essential to efficient materiel management. These do not exist in the Marine Corps at present. The current definition of unserviceability in Marine Corps materiel programing is the set of condition codes in the Marine Corps Supply Manual (see Table V). These codes describe the condition of equipment as estimated repair cost expressed as a percentage range of the acquisition cost of the equipment. The underlying assumption is that the costs for repair of two or more types of equipment in a similar substandard condition is directly proportional to the acquisition cost of the types of equipment. This may or may not be the case in practice.

The condition code now in use does not indicate how unready for service an individual piece of equipment may be but reflects only the costs required to repair it. For example, the acquisition cost of an M35, 2-1/2 ton tactical vehicle is $6,800. Assume (only for the purpose of illustration) that an M35 is in all respects ready for issue except that it requires replacement of a set of tires, a battery, and canvas. The cost of these items is about $750. Such a truck would be condition coded R-2 even though not a single repair was required. It could be restored to full service almost immediately at the organic level. The code does not indicate whether the return to serviceable condition is within the capability of organic or field maintenance echelon or whether the restoration to serviceable condition is more appropriately 5th Echelon work.

Recent emphasis on component replacement programs at field maintenance echelons increases the need for clearer definition of what work is most properly field maintenance. For example, the replacement of an engine and transmission in a jeep would exceed the R-2 condition code limits, but is a simple job within the capability of 3rd Echelon maintenance, perhaps even 2nd Echelon. On the other hand, the accumulation of repairs to reach the upper limits of R-2 in an LVTP5 would require much more field maintenance effort, especially if the replacement of major components is not required.

From the manager's point of view the condition codes have the advantage of universal application. However, such universality may in itself be misleading. To illustrate, the upper limit of R-2 for an LVTP5, which has an acquisition cost of $125,000 is $31,250. The upper limit for the same code for the $1,990 M38A1 Jeep is only $497.50. The R-2 thus represents a great range of potential costs. Field interviews revealed considerable criticism to the effect that much equipment was being evacuated to 5th Echelon that did not require that level of repair. It is interesting to note that such criticism came both from field maintenance and supply center officials. However, consistent answers could not be obtained on what did and did not merit 5th Echelon rebuild. One experienced motor transport field maintenance officer, in fact, stated that only two conditions were beyond the scope of his field maintenance activity: extensive body work and frame straightening.

The body work facilities at the two MCSC repair centers are minimum. A current Marine Corps directive specifically prohibits frame straightening at 5th Echelon.* In effect, then, the field maintenance officers' comment meant that the proper role of depot maintenance is to serve only as an overflow outlet for field maintenance. In some cases this may be true, but we doubt that such measures can be universally applied. Not only do condition codes fail to give an accurate picture of equipment unserviceability, they do not indicate at what point of unserviceability equipment should be evacuated to 5th Echelon. Only Code X makes reference to equipment disposition, and then only inferentially.

Table VII is taken from the NAVCOMPT Integrated Audit of the Marine Corps 5th Echelon Repair Program. This table is quoted to show the great

Table VII

EQUIPMENT RECEIVED AT MCSC, BARSTOW, FROM R&E PROGRAM
Calendar Year 1960

	Condition Codes Assigned by MCSC, Barstow					Number of Equipment
Equipment Category	R-1	R-2	R-3	R-4	R-5	Items
Motor transport	45	864	571	217	41	1,738
Communications--electroni s	-	27	-	-	-	27
General supply	-	2	2	-	-	4
Engineer	-	15	21	6	3	45
Ordnance	-	69	125	15	1	210
Total	45	977	719	238	45	2,024

Source: Office of Comptroller, Department of the Navy, Marine Corps Fifth Echelon Repair Program (Integrated Audit Report No. IA2-61 Issued 6 Oct. 1961), p. 4.

* Marine Corps Order 11245.2 Sup. 36 Ch. 1. Subject: Minimum standards and procedures for fifth echelons reconditioning of motor transport equipment, dated 24 Feb. 1961.

variance in the condition code of equipment received at the supply centers. It is not within the scope of this study to determine the proper condition of equipment for evacuation. It is germane, however, to note that there should be some relatively definable condition of equipment which makes it eligible for evacuation to rebuild. Table VII indicates that this is not the case at present. Approximately 5 percent of all the equipment evacuated is codes R-1 and R-5 (Code X); approximately 48 percent is R-2; approximately 31 percent is R-3; and approximately 11 percent is R-4. Which of these condition codes properly reflects the condition of equipment valid for 5th Echelon work is another matter. It is obvious that all of them cannot simultaneously be correct. The report from which Table VII is drawn precedes these figures with the following remark:

> The audit at MCSC Barstow disclosed that equipment received during calendar year 1960 under the R&E Program was assigned condition codes upon receipt as follows:

Just how such equipment was identified as having come from the R&E Program is not clear to us. Our attempts to segregate equipment previously received at either of the Marine Corps supply centers as having come from R&E indicated that a laborious item-by-item, record-by-record check would be required to establish the source of such equipment, and in most cases, such records were not available. In fact there is not even an organized system to test whether the equipment arriving at 5th Echelon from the R&E Program is in a condition which merits rebuild/repair work at that echelon. While the evacuating organization is required to perform a limited technical inspection prior to evacuation, there is no published common standard by which the inspector's estimate of the cost and scope of work can be related to the standards followed at 5th Echelon, or even to those of another unit at 3rd of 4th Echelon, since local practice varies.

It appears to be the common practice at 5th Echelon to ignore the previous LTI and perform a new inspection, and there is no attempt to reconcile the 5th Echelon inspection with the previous LTI. As now organized, 5th Echelon has no particular interest in the source of individual items of its maintenance load. An item which had identity as a piece of individual equipment in the field is considered as only an asset at the 5th Echelon, and as an unserviceable asset, is treated like all other unserviceables of the same type. If the arriving asset is not scheduled for induction in the current Master Work Schedule, it will most likely be given a condition coding inspection and removed to a holding park as FRC 14 materiel. It may remain there for a period of months or even years before it is scheduled for induction to the repair activity and given a more or less thorough inspection for the purpose of generating a bill of materials and for other planning and estimating purposes.

Equipment at 5th Echelon may have deteriorated in storage to the extent that inspection does not reflect the condition of the equipment at the time of evacuation. Whatever the case, there is no attempt to identify the asset as having come from the R&E Program, and there is no systematic recording of the evacuation condition of the equipment in terms precise and meaningful to both the 5th Echelon and field echelon. Thus, at the supply center repair divisions, the places best qualified to judge the efficacy of R&E to rotate equipment equitably and at the optimum time in respect to maintenance, there is no attempt to even consider whether R&E accomplishes this. It should be stated from their standpoint that the repair divisions have good reasons for these practices, but this is beside the point in this study since the present system does not assist in optimizing equipment replacement programing for the Fleet Marine Force.

In order to strike an equitable balance between workload at field maintenance echelon and 5th Echelon, a set of detailed standards based on mechanical condition is required in addition to the present dollar-based condition codes. A comparison between the estimated costs of a given repair in the field and at the depot will almost invariably appear to favor doing the work in the field. Such comparisons are grossly misleading however because of differences in the way overhead and other real costs are treated. Furthermore, they are in some cases dangerous. They neglect consideration of the implications to the mission of the organic and field echelon maintenance activities. If workload is imposed on FMF maintenance on the basis of only dollar considerations, FMF combat service support may evolve into an efficient garrison activity that is poorly equipped for combat service support.

Efficient replacement programing requires a detailed item by item listing, both by equipment and by component within an equipment (where components are common to various equipments, they may require different standards of serviceability). Much of the basis for such standards is already available in the USMC. Two examples, which are not directly applicable in their present form, are: MCO 11245.2, Sup. 36, and Form 11 ND-MCSCB 4/30/3 (4-61). The first is titled, "Minimum Standards and Procedures for Fifth Echelon Reconditioning of Motor Transport Equipment" and the second, "Inspection and Repair Work Sheet for Wheeled Vehicles." The latter was developed locally for use in the MCSC, Barstow, Repair Division, and provides an example of a comprehensive equipment-oriented check-off list. The Marine Corps Order, which enumerates standards to which equipment should be repaired at 5th Echelon, would provide the basis for standards describing conditions in equipment which should be repaired at that echelon.

Standards should be arranged in such fashion that evolutionary changes in requirements and conditions could be accommodated with minor revision. For example, there is currently a large backlog of unserviceables at 5th Echelon. Accordingly, further evacuation of unserviceables for the near future should be minimized and highly selective. As the backlog situation improves at 5th Echelon, however, it may become economically feasible to evacuate equipment that it was not feasible to evacuate earlier. Standards and definitions for evacuation to 5th Echelong should be so written that future needs could be satisfied by a modification of existing standards rather than a completely new directive.

Limited Technical Inspection

Marine Corps policy requires that a limited technical inspection be performed at field or user unit level prior to the evacuation of equipment to 5th Echelon for rebuild or to Redistribution and Disposal for salvage. This inspection is a most critical point in effective replacement programing. On the basis of this, the future of individual pieces of equipment is decided. If the equipment is sent to salvage, the decision is essentially irrevocable. If the equipment is evacuated to 5th Echelon, a subsequent decision at the supply center may send the equipment to salvage but only after considerable transportation and handling costs have been incurred. If equipment is evacuated to 5th Echelon prematurely, there is little alternative to cycling it through rebuild, even though this wastes rebuild funds.

Because the LTI in the field is the basis for such critical management decisions, it is important to consider in detail the procedures followed in LTI's

The study team conducted field interviews with senior management officers and with shop personnel in most of the major field echelon maintenance activities in the Marine Corps. Although there are differences from command to command and from equipment type to equipment type, a fairly consistent pattern of procedure seems to be followed in the performance of LTI's. The inspectors who perform the LTI's are almost invariably the more skilled mechanics in their group. Their technical ability to perform competent inspections is unquestioned in our observation. The art of inspection and trouble shooting is an essential ingredient in the skill of maintenance repairs. Errors in the LTI procedure appear to be more a function of the degree of thoroughness permitted the inspection team by time, workload, and other constraints, and the methods used in estimating costs, rather than the skill of the inspectors. The LTI is a more or less gross examination of equipment and does not include opening up components for detailed inspection. To do so would involve a very heavy expenditure of skilled manpower which is already in scant supply. However, a skilled mechanic can determine much of the requirement for repairs in such an inspection, particularly when diagnostic tools and equipment are used.

On the basis of the LTI, the inspector estimates, in terms of his own shop facility, the parts and manpower required to perform the repairs. Where repairs can be performed without major disassembly of the components, the cost of spare parts are taken from the cognizant stock list. We noted a varying policy as to whether an estimate of the man-hours of labor required to install these repair parts is made. In some cases, the cost of labor is estimated; in other cases not. Where labor hours are estimated, there is a varying policy as to the price at which labor hours are costed. In no instance did we find any accurate knowledge of the cost of labor at the supply depot repair centers, nor observe any attempt to obtain such figures as the basis for estimating the cost of labor to accomplish requisite repairs.

Where replacement of components is indicated by the LTI, the general practice is to cost the repair at the stock list price of a replacement component. In no instance investigated by the study team was the cost of labor to remove and reinstall the component included in the estimated cost of repair.

The costs of all individual repair processes are then aggregated to the total. There is a difference between the method in which this is done for various classes of equipment. For example, the LTI form for tactical motor transport indicates the individual cost for each of the several components on the vehicle and these costs are summed to obtain a total. For other equipment, the resultant cost to repair is expressed only as falling within one of the condition codes (R-code). But in any case, estimated costs to repair the various components must be computed in order to derive the over-all cost to repair, whether this cost is expressed in dollars and cents or as a condition code. On the basis of the estimated cost to repair, the decision is made as to the ultimate destination of that individual piece of equipment. If the estimate exceeds prescribed limits, the equipment is sent to salvage. If the estimate does not exceed these limits, the equipment is evacuated to 5th Echelon for eventual rebuild.

In passing it might be noted that the LTI's tend to fall into a pattern at a given locale in a given organization. Frequently, they reflect fairly standard estimates as to the value of component repair costs. Such standardization should not, in itself, be interpreted as reflecting an inadequate inspection. Repairs for a given component within a shop of a given capacity and level of efficiency should be relatively standard for several reasons. Once the repair is inaugurated, certain work is done to all components in the course of the repair. Further, once work begins on a given component, work in addition to replacement of the part causing the repair is done. Assembly and disassembly times for an engine, for example, are relatively standard, regardless of the scope or work involved inside the engine. Once the engine is opened, considerable work not urgently required is frequently performed at the same time. This anticipation prevents early recurrence of repairs. Once work begins on a particular piece of equipment, with little additional work a full repair can be effected, rather than the bare minimum requirements indicated by inspection. This tends to standardize repair estimates.

When evacuated equipment arrives at 5th Echelon it is given another condition code inspection by an MCSC inspector.* The inspection form used may follow the format of the field form, but it is usually locally derived. The inspector may use forms in addition to those used in the field inspection. The MCSC condition code inspector pays close attention to both estimated labor costs and parts costs. As a guide to estimating labor repair costs the inspector uses the Engineered Standards estimates (if they are available for the equipment type) or the best historical estimate for previous work of a similar nature at his repair division. Table VIII is a sample of the Engineered Standards followed by the MCSC, Barstow, inspector. Thus, the 5th Echelon uses an entirely different set of standards to estimate the same job estimated earlier in the field. On the basis of the 5th Echelon inspectors' estimates, the equipment will be sent to salvage, inducted for repair (if in a line item of the Master Work Schedule), or deferred for later rebuild.

To examine the different methods followed in field and depot condition coding inspections, an analysis was made of a group of evacuated M35, 2-1/2 ton trucks. From 133 LTI's made on M35 trucks by 2nd Force Service Regiment, Camp Lejeune, the study team took as a statistical sample the LTI forms for all M35's with a U.S. Marine Corps number ending in the digit 4. This sample was approximately 10 percent of the

---

* In no case did we find that the MCSC inspector referred to the field LTI in deriving MCSC condition codes.

Table VIII

M35 ENGINEERED STANDARDS ESTIMATES - MCSC, BARSTOW

	Labor—All Shops (man-hours)	Cost of Material
Rebuild M35 truck		
Engine	48.6	$152.50
Transmission	7.6	46.00
Transfer case	13.8	140.00
Axle assembly, front	10.9	240.00 est.
Axle assembly, rear	8.7	188.00 est.
Radiator	3.5	No data
Gas tank	2.9	No data
Remove and install M35 truck		
Engine	10.0	
Transmission	3.2	
Transfer case	3.9	
Differential, front	No data	
Differential, rear	No data	
Radiator	1.5	
Gas tank	0.5	

Source: Chief Inspectors Office, Repair Division, USMCSC, Barstow, Calif.

total LTI's available and included data on trucks from several units. After this random selection, spot checks were made of the balance of the LTI population. The sample was representative of the whole, and was especially representative in terms of the components selected for the analysis. Eleven M35's were selected for detailed study. Of the eleven, eight were priced as follows:

Engine repair	$187
Transmission repair	36
Transfer repair	12
Axle repair, 3 axles at $9 ea	27
Total	$262

For comparison purposes, the Engineered Standards estimates followed by the condition code inspector at the Repair Division, U.S. Marine Corps Supply Center, Barstow, were obtained (see Table VIII).* Labor costs at the supply center were obtained from the Operational Cost Report, First Half Fiscal Year 1961, MCSC, Barstow. These costs were as follows:

Overhead	$2.53 per direct man-hour
Direct labor (civilian)	2.72 per man-hour
Direct labor (military)	1.44 per man-hour

The cost of labor plus overhead was then multiplied times the man-hours of Engineered Standards, "labor all shops" figure shown in Table VIII. The resultant totals for labor were in each case added to the Engineered Standards estimate for materials required to complete the repairs. The total cost estimated equaled $1,477.42 for 5th Echelon civilian labor

* The comparison is made for illustrative purposes only. That the M35's sampled were actually evacuated to MCSC, Albany, is not really relevant. The MCSC, Barstow, standards were used because they were available. Had Albany standards been available they would have been used.

and $1,343.75 when the computations were based on 5th Echelon military prices. In each case, overhead was added to the direct labor cost, inasmuch as this is the practice for management reports at each of the 5th Echelon repair activities.

Two of the LTI eleven-truck samples estimated engine repairs at $168, but this cost was the only significant change from the estimates shown for the eight LTI's just described. Use of this cost would have increased the discrepancies between the field and 5th Echelon costing methods.

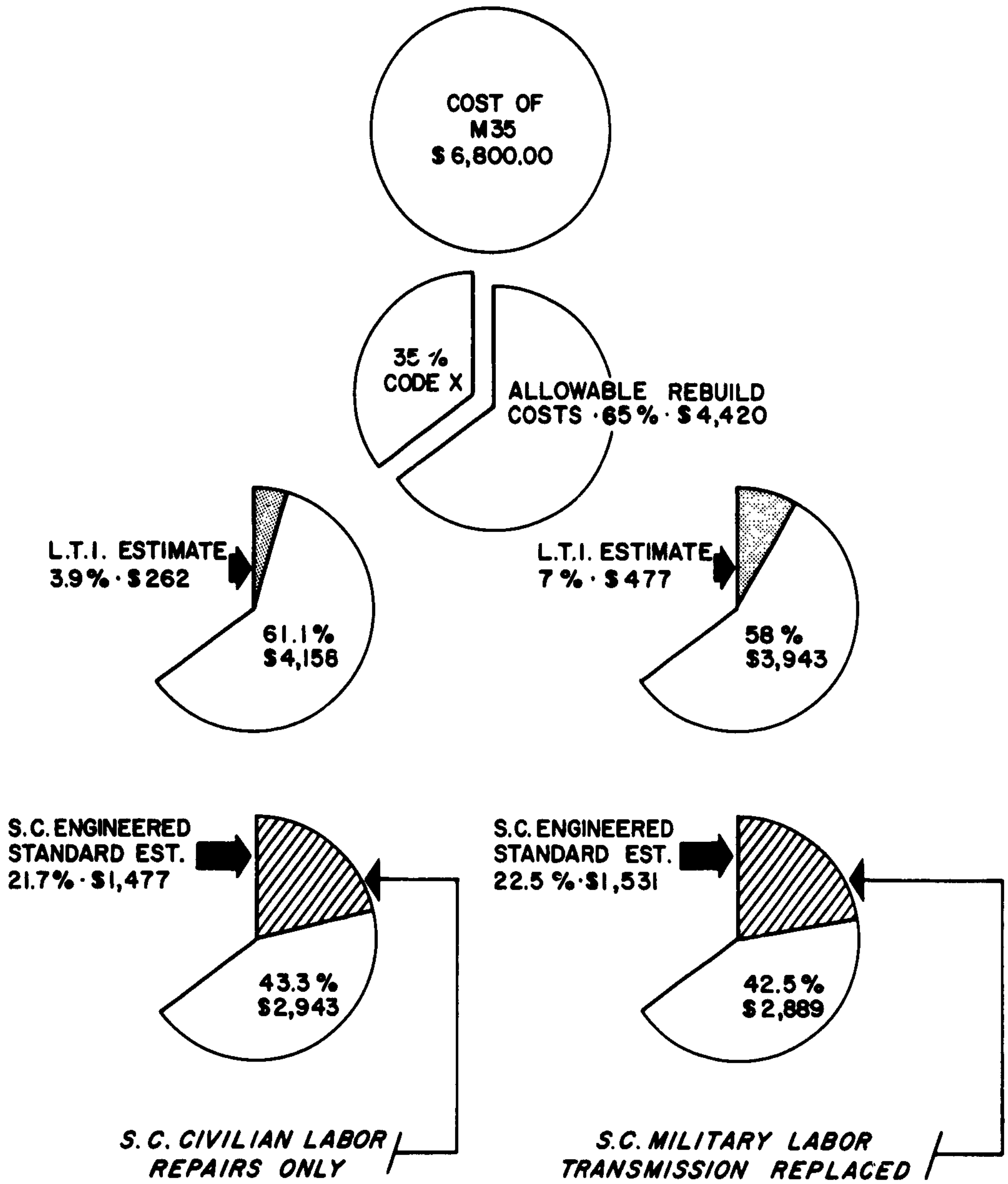
In the case of a transmission replacement, the LTI forms showed the replacement cost listed as $251, the stock list price for a replacement transmission. The cost does not include any labor for removal of the replaced transmission and installation of the new transmission in the M35. In the analysis, the 5th Echelon estimates were based on the price of the replacement transmission plus the man-hours indicated in the Engineered Standards estimates for removal and installation of the equipment in the truck.

Figure 11 illustrates the result. Let the circle at the top of the figure represent $6,800, the stock list price of an M35, 2-1/2 ton tactical vehicle. By current directives, 65 percent of that is available for rebuild costs. This $4,420 is indicated in the next circle below. The two lower left circles compare the cost estimates (shaded area) for repairs by the LTI method and the supply center Engineered Standards method priced at supply center civilian labor costs. The differences between the value remaining for other repairs is illustrated by the relative sizes of the unshaded areas of the two circles.

In the two diagrams at the right, the LTI and Engineered Standards estimates for the same work are compared again, except that in this case a transmission is replaced rather than repaired and supply center military labor costs are used. Again the difference between the two estimates is indicated by the relative size of the unshaded areas.

There is a general misconception that the supply center condition code inspector has a unique insight into the details of repair processes by virtue of being located at MCSC. Actually, this inspector usually works outside the repair shops and has little professional contact with the repair process. His inspection is no more valid than the set of estimating standards he receives from the repair activity.

We have already remarked the practice of applying locally derived standards in the LTI procedure. Since standardized estimates are



SOURCE: NWRC, Stanford Research Institute.

FIG. 11 LIMITED TECHNICAL INSPECTION ESTIMATES vs. SUPPLY CENTER ENGINEERED STANDARDS FOR SELECTED M-35 REPAIRS already being used, a different set of standards for the evacuate/salvage LTI should not complicate LTI administration in the field. The simple procedure of supplying field maintenance echelon the same information now provided the MCSC condition code inspector would provide a common standard for successive inspections in the evacuate/salvage decision process.

It is appreciated that Engineered Standards estimates are not available for the full range of Marine Corps equipment at the two 5th Echelon activities; however, the development of such standards is in continuing process. Where these standards are available, and as more become available, they should be used in making the decision to forward work for 5th Echelon processing. Where such Engineered Standards estimates are not available, the data which is presently used by the condition coding inspector at the two supply centers could be provided to the field LTI team. Whether accurate or not, these data are certainly a closer reflection of the 5th Echelon's performance than are the estimates based on field echelon maintenance.

Further improvement in equipment replacement programing could be realized by following the same procedures and standards in the field as are now followed by the supply center coding and induction inspectors. The inspection ability and much, if not all, of the equipment necessary are already available in field maintenance. What is lacking is distribution of the common procedure. Repair Division Order 4855.7 issued by the Repair Division, Marine Corps Supply Center, Barstow, California, is an illustration of comprehensive repair inspection standards. These standards, for the most part, pertain to the inspection of repair division work by the quality control inspectors for the division. However, much of the information and procedures contained in the order are of value to the preinduction inspector at the supply center, and are currently used by him. LTI teams at field maintenance that are faced with the problem of evaluating the repair-salvage-evacuate destiny of equipment could profit from the same procedures. It is our understanding that a similar document is in process of preparation at the repair division, Marine Corps Supply Center, Albany, Georgia.

The use of the directives from MCSC, Barstow, and MCSC, Albany, as a basis for development of a common procedure for the cognizant field echelon maintenance activities served by each of the two repair divisions would result in similar standards being followed at both field and repair depots. If there are differences between MCSC procedures, two such guides would be required at the repair depot. These would go a long way toward insuring that only that equipment most properly suited for a 5th Echelon rebuild is in fact evacuated to the repair divisions.

The use of the 5th Echelon data would provide an additional advantage in that LTI's performed in different locations in the field could be compared with one another, thus affording program managers at the FMF fleet level and at HQMC a set of comparisons of the equipment condition in various units. Because the same data and the same format would be followed, there would be the further advantage of providing an automatic accuracy check on the several inspections performed on equipment.

In addition to repair cost, the LTI procedure estimates the cost of equipment and materiel which are not repair items. For example, in tactical vehicles, batteries, canvas, cargo bows, and other materiel which is readily installed straight from supply sources is included as estimated repair cost in the LTI procedure. Although an accurate estimate of such cost is necessary for over-all materiel management, the practice of including these supply items within the estimate on which an evacuate or salvage decision is based is misleading. This is particularly so if such consumable stock items are a significant proportion of the total estimate to restore to serviceable condition. First, such costs inflate the total repair estimate and may cause premature evacuation of equipment to rebuild.* Second, the net effect of a decision to evacuate based on inflated costs is to increase the required USMC inventory of supply items as well as end-items. For example, when the decision is made to evacuate an M35 truck requiring 11 new tires, a requirement is immediately created for two M35 trucks and 22 new tires (11 on the replacement, 11 on the one being rebuilt).

Table IX illustrates the degree to which the effect of including supply items as an integral part of total repair estimates obtained in the 2-1/2 ton M35 tactical vehicles example. The table summarizes LTI on 133 M35's. Of the 133, 123 were coded R-2. Two were coded R-1, and eight were coded R-3. The estimates to repair the two R-1 vehicles were $658.80 and $597.11 respectively. Those coded R-2 ranged in estimated cost between $688.69 and $1,685.44. The R-3 ranged in estimated cost from $1,706.88 to $2,186.10. The over-all average estimated cost of

---

* It is current Marine Corps policy to require user units to fund from the unit budget the cost to replace consumables on equipment retained in service, but not to charge the user units for the cost of such material furnished on replacement equipment. The cost of off-the-shelf consumable items can reach significant proportions. For example, the cost to replace the tires, battery, and cargo bows for an M35 truck is approximately the same as the cost of a replacement engine.

Table IX

ESTIMATED TOTAL REPAIR COSTS VERSUS CONSUMABLE COSTS FOR M35 TRUCKS

Condition Code	Dollar Limits[a]	No. of Trucks	Estimated Total Repair Cost			Consumable Costs			Consumable as a Percent of Total Repair		
			Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
R-1	$ 680	2	$ 658.80	$ 597.11	$ 627.96	$344.00	$169.00	$256.50	57.6%	25.7%	41.7%
R-2	1,700	123	688.69	1,685.44	1,283.54	840.00	169.00	737.43	67.7	18.0	56.8
R-3	2,720	8	1,706.88	2,186.10	1,846.47	840.00	344.00	681.14	49.2	20.0	37.0
R-4	4,420	0	--	--	--	--	--	--	--	--	--
All		133	658.00	2,186.10	1,307.54	840.00	169.00	726.81	67.7	18.0	55.4

a. Based on stock list price of $6,800 for M35.

repair of the 133 vehicles was $1,307.54, i.e., 19.2 percent of the $6,800 acquisition cost of the M35. The cost of consumables was the sum of the prices shown on the LTI forms for batteries, tires, vehicle accessories, canvas, and cargo bows.

When the cost of these consumables is compared with the total estimated cost of repair (see Table IX) it can be seen they average 55.4 percent of the value of the original estimated cost to repair of the entire M35 sample. In one case the cost of the consumables was more than 65 percent of the estimated total cost to repair. In only 12 cases was the cost of consumables less than 40 percent of the total cost to repair (about 10 percent of the cases). If the cost of consumables indicated on the 133 LTI forms studied were subtracted from the total estimated cost to repair, the average R-2 estimate would be an R-1 estimate, and in each case those coded R-3 would be R-2.

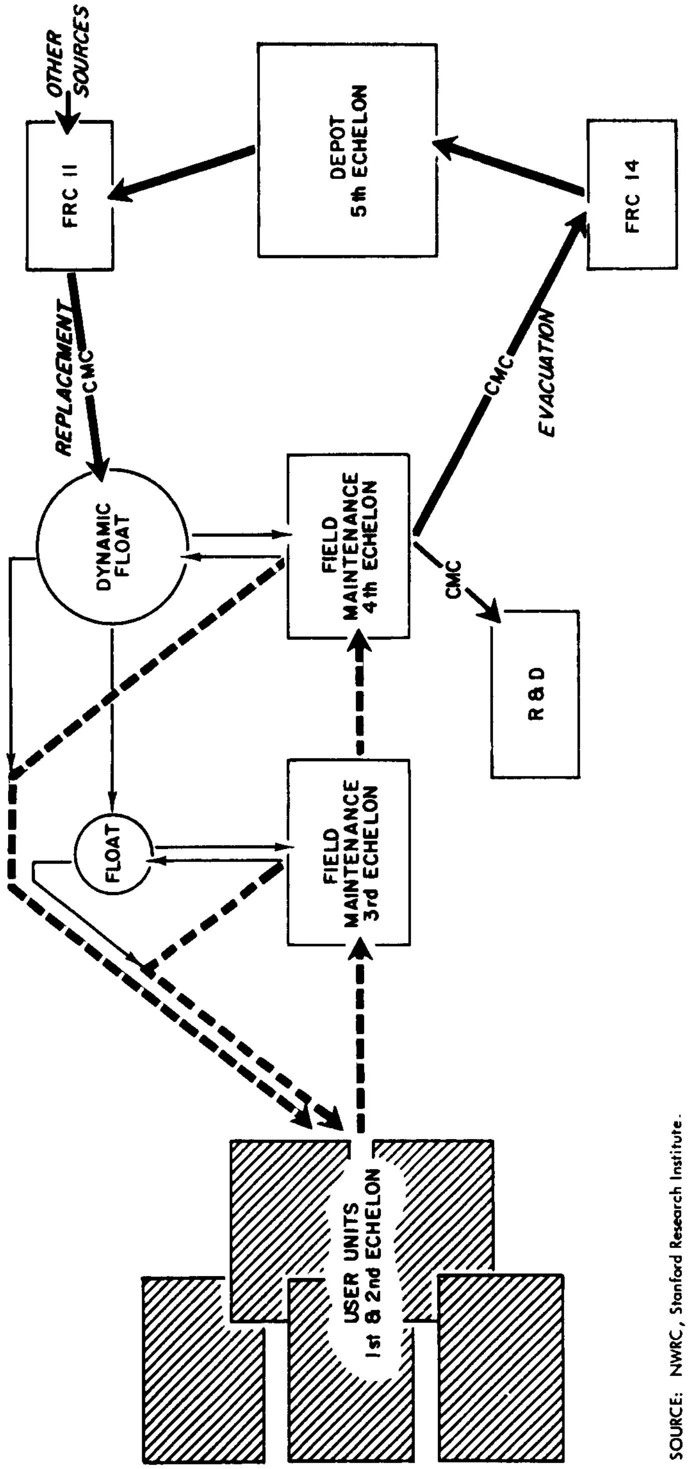
It is suggested that the cost of nonrepair items be segregated from the cost of repair estimates at the time the decision is made to either send to surplus or evacuate to 5th Echelon. This will give a more accurate estimate of the actual repairs required to restore the equipment to serviceability.

V A DYNAMIC FLOAT FOR EQUIPMENT REPLACEMENT

Some method of retaining the merits while correcting the disadvantages of the R&E Program is required. The problem is how, with minimum innovation, to achieve continuity, realism, responsiveness, and economy in the FMF equipment replacement program. At least the beginnings of just such a program appear to be present in the current Marine Corps materiel program--namely, in a broadened concept of the recently established field maintenance float. Most of the disadvantages of R&E might be corrected if the flow of replacement equipment were diverted into a float at the field maintenance level and if at the same time all the evacuated equipment were required to move up through the echelons of maintenance. Such a float should be dynamic in the sense that its size and composition should change in direct response to the needs of the units supported, as opposed to the fixed or static maintenance float now beginning to operate.

Figure 12 illustrates the operation of the suggested program. The heavy broken lines indicate the flow of equipment between user organizations at 1st and 2nd Echelons and field maintenance at 3rd and 4th Echelons; however, now 4th Echelon deals with the supply depot as indicated by the heavy solid lines. This relationship appears much more coherent than the present system. Definition of the actual maintenance by echelon is at best a tenuous matter, but there is a much better correspondence of viewpoint between 4th and 5th Echelon than between 5th and any other.

The system would work as follows: A user organization would deliver a substandard equipment item to 3rd Echelon, just as it does today. If the equipment item could be returned to standard performance there, it would be repaired and returned to the user. If repairs were beyond 3rd Echelon capability, the equipment item would go to 4th Echelon. If its serviceability could be restored there, the equipment item would be returned to the user after maintenance. On the other hand, if repair was beyond field maintenance capability, a serviceable replacement would be issued to the user from the float. Then, according to the category and condition of the equipment, 4th Echelon would either "wash it out" to Redistribution and Disposal for salvage, or evacuate it to 5th Echelon according to definite standards issued by Headquarters, Marine Corps. These standards should reflect not only the condition of the equipment



SOURCE: NWRC, Stanford Research Institute.

FIG. 12 MAINTENANCE ECHELON RELATIONSHIPS UNDER A DYNAMIC FLOAT PROGRAM and the projected requirement for the asset in the future, but also the need for unserviceables for induction at 5th Echelon.

In the normal course of service, individual equipment is nominated for salvage or evacuation by arriving at some defined condition of substandard performance. Field maintenance simply selects the worst of the equipment it receives, and replaces it according to actual need. The poorest equipment in the area is that on which field maintenance normally works. Thus the selection of poorest equipment in the area is made at the echelon level best qualified to judge the over-all condition of equipment among all the units supported.

Most major Marine Corps equipment does not fail in catastrophic fashion, but experiences progressive deterioration in performance. It is already a part of the day-to-day duty of organic and field maintenance personnel to detect and diagnose failure in order to perform their maintenance function. Inspecting for present substandard conditions, then, is already within the state of the art. Long-range forecasting of the future state of unserviceability for specific pieces of equipment is at best experienced guesswork. It would follow then, that if other program requirements can be satisfied, it is best to replace individual equipment on the basis of its actual, not some distantly anticipated, condition.

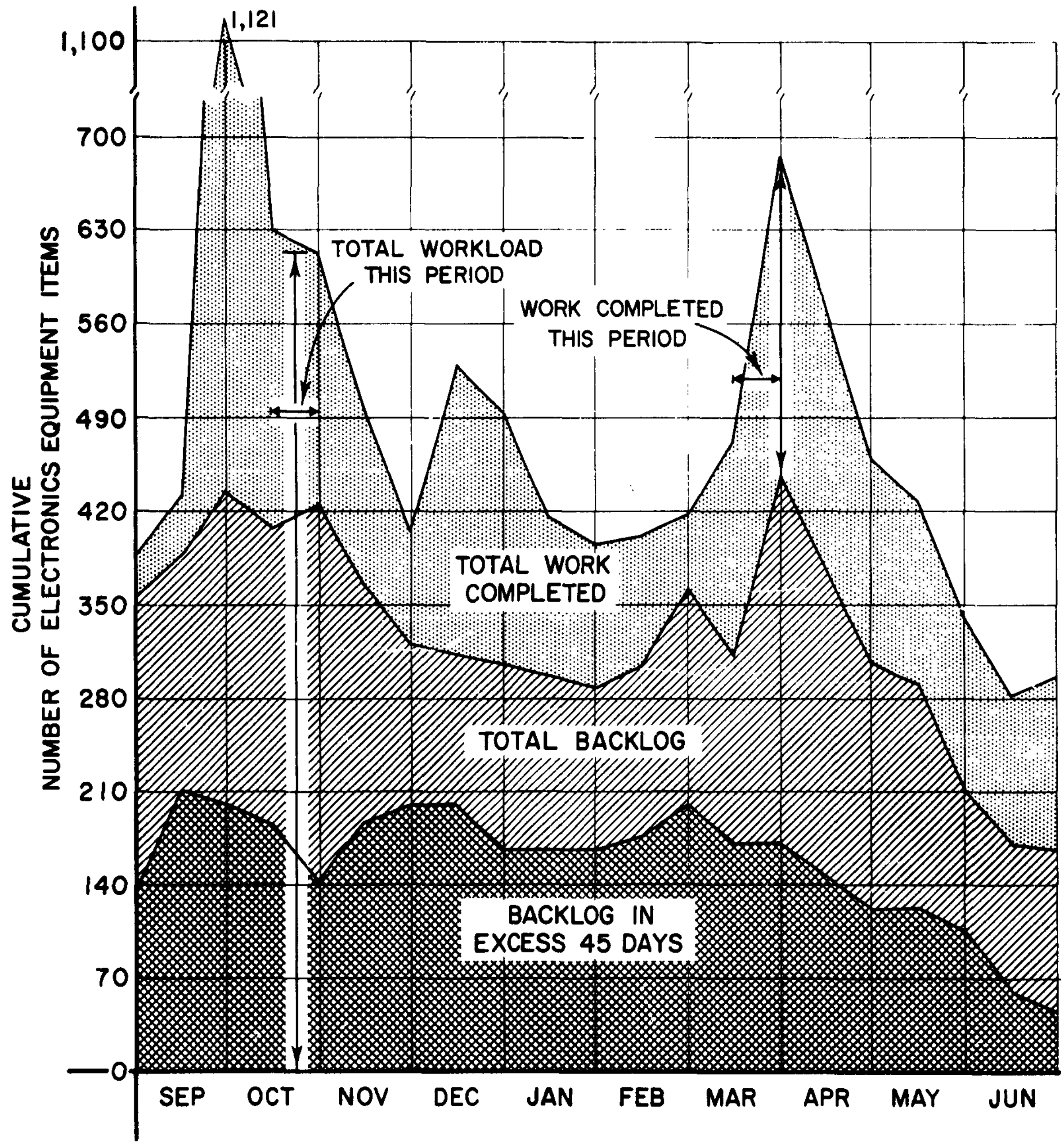
Several advantages are immediately apparent. The user unit is still assured a full table of equipment. Because there is no pressure to evacuate in order to make a place for replacement equipment in the user table of equipment, more economic use can be made of remaining service life of equipment. Because the float is prepositioned, there is no need for user organizations to make long-range forecasts concerning the future state of serviceability of individual equipment.and there would no longer be a requirement for recurring LTI's for replacement candidates. Neither is a unit required to retain unserviceables because of earlier miscalculations.

Since the decision to evacuate to salvage or 5th Echelon would be made in a single place for a given area, another benefit would result. Equipment in a more homogeneous condition of unserviceability would be evacuated to 5th Echelon, thus contributing to the efficiency of repair facilities there. At the same time, the burden of recurring limited technical inspections to select the worst equipment from user units in an area would no longer be required. Nor would the transfer of used equipment between units in an area be required. A standard condition of unserviceability could be arrived at in the simple course of the day-to-day operation of 4th Echelon maintenance. User units would receive replacement equipment on the basis of actual need at the time the need occurred--and only at that time. Since the occurrence of unserviceability appears to occur in almost random fashion (because of the varying contribution of the many factors governing unserviceability) replacing equipment at the time of actual need would be the best protection against block unserviceability. In other words replacing equipment as it becomes unserviceable is the best defense against all equipment becoming unserviceable simultaneously in the future.

Other advantages also occur. Field maintenance is required to perform only to a given standard under the dynamic float system. It is not required, for example, to support equipment items which have arrived at unserviceability earlier than predicted. Field maintenance emphasis could be placed on maintaining those equipments as defined within the proper scope of field maintenance activity. A larger float on which to draw would allow field maintenance to achieve even fuller benefits from the present field maintenance float concept because pressures for immediate performance on the individual pieces of equipment could be removed and work scheduling could be more properly and efficiently planned by rotation of equipment in and out of the float.

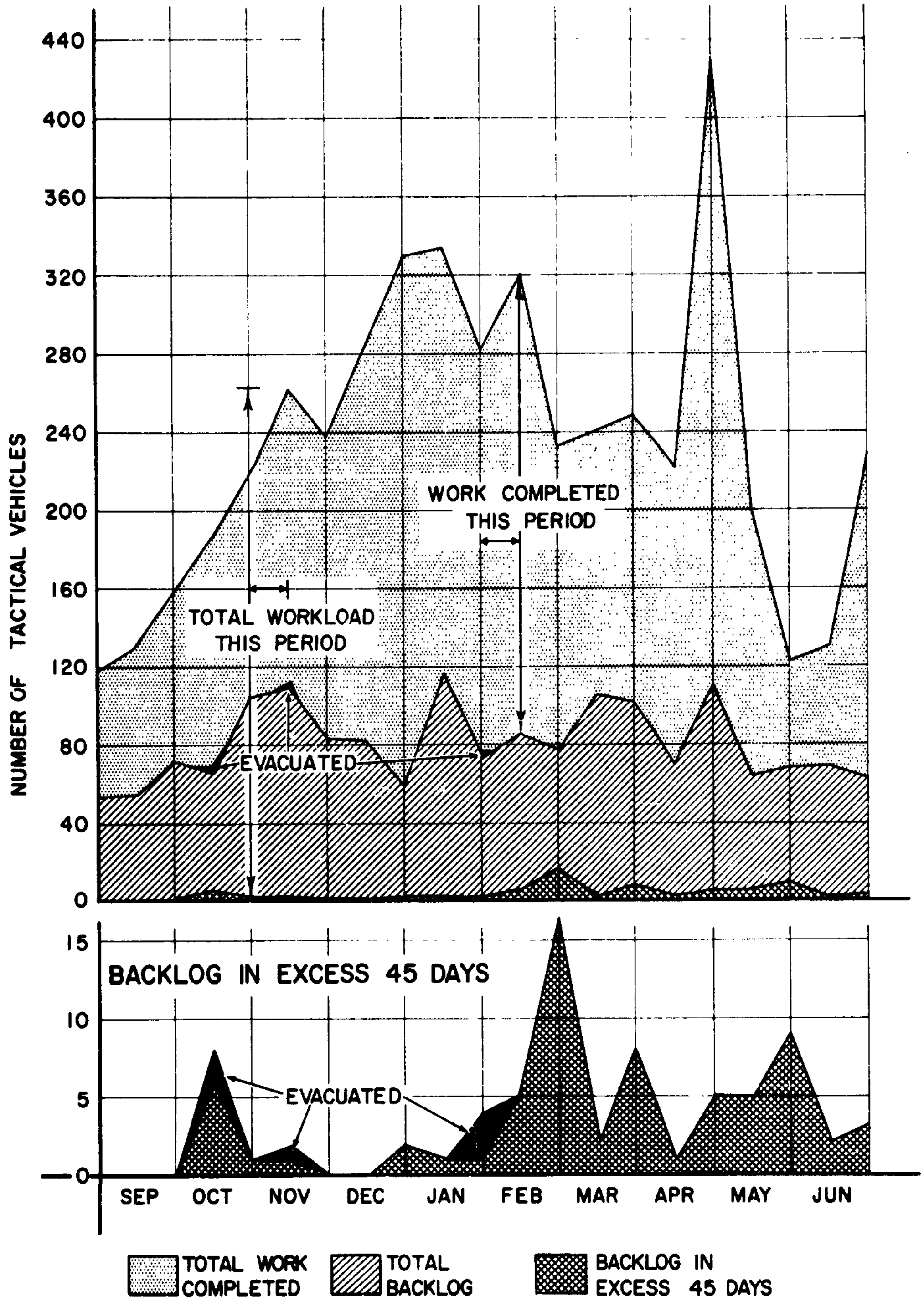
The capacity of a field echelon to perform maintenance is an important facet of equipment replacement programming. Figure 13 shows the operation of the electronics maintenance activity of the MS&M Battalion of the First Force Service Regiment during the period September 1960 through June 1961. This period was selected because changes in report format prior to and after the period made comparisons difficult. The vertical axis shows cumulative pieces of equipment. Time in months is plotted along the horizontal axis. At the end of October the backlog in excess of 45 days was 140 pieces. The total backlog at that time was about 420 items of equipment. Backlog in excess of 45 days is a part of total backlog. The total workload for the previous half month is 614 units. Work was completed on 190 pieces of equipment in the last half of October. Figure 14 is a similar plot of tactical motor transport maintenance.

The first general impression received from these charts is that the over-all trend in both classes of backlog appears to be downward. Another more subtle point is that the capacity of the batallion to complete work (shown here by the height of the zone between total backlog and total workload) fluctuates rather widely, but seems to follow a pattern. The work completed for a period appears to be some function of the total workload imposed on the shop rather than of a fixed capacity.



SOURCE: NWRC, Stanford Research Institute.

FIG. 13 ELECTRONICS MAINTENANCE AT MS&M BATTALION, 1st FSR, FMF



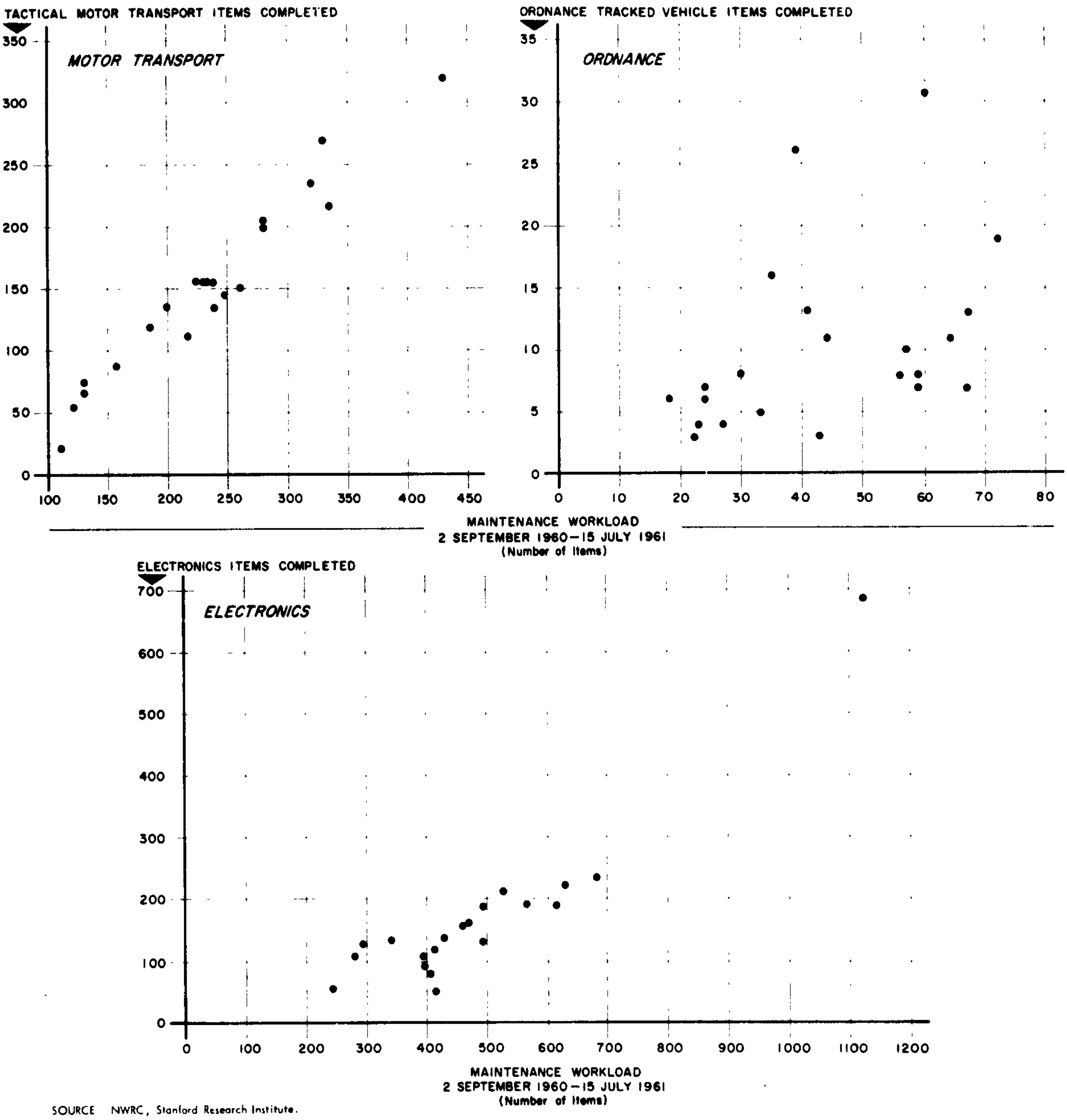
SOURCE: NWRC, Stanford Research Institute.

FIG. 14 MOTOR TRANSPORT MAINTENANCE AT MS&M BATTALION, 1st FSR, FMF

A similar pattern developed in other analyses of 4th Echelon maintenance. These are shown in the charts in Figures 15 and 16. It would be expected that workload and work completed would follow a fairly close relationship but that at some point the work completed would arrive at a maximum figure, regardless of additional workload imposed. That such is not the pattern can be seen in the charts of Figures 15 and 16. This capacity to produce under pressure leads us to assume that the float calculation should be based on the excess backlog rather than on the much larger total backlog.

It should be noted that some backlog will always be present during normal reporting periods. The reporting periods are arbitrarily established for administrative purposes and are in no way connected to the way maintenance work is received or inducted into the shop. Thus a maintenance report will cover a two-week period and will include many items of equipment inducted for work during the last several days of the report period and on which there has not been time to perform repairs. On the other hand, the excess backlog is composed of items not repaired for a variety of reasons. Usually, equipment is retained in the excess backlog category because of a lack of correct repair parts. In other instances, excess backlog might be an indication of shop inefficiencies caused by limited shop space, personnel, skills, or repair equipment. In general, however, it can be assumed that equipments reported in excess backlog are beyond the present capability of the maintenance activity to repair. Much of the equipment carried in backlog status, whether current or excess backlog, is equipment which is only marginally unserviceable and which might be available for issue in case of mount out. For example, included in both the current and excess backlog categories in Figure 13 are some PRC10 radios which are serviceable except for the fact that the waterproof cap for the antenna was not available. Materiel management dictated that these radios not be issued for field use in this condition, since use, even in training maneuvers, might cause deterioration which would make the radios actually unserviceable. Such exceptions to the contrary, the backlog at field maintenance echelons is observed closely by cognizant officials as one measure of the materiel readiness of the unit supported as well as of the efficiency of the field maintenance echelon.

The ideal dynamic float (see Figure 17) would equal the number of unserviceables generated by the units being supported over a given time period, less the capability of field maintenance for that period. More simply, the ideal float equals the backlog at the field echelon plus the equipment which actually requires evacuation. In practice this ideal float might provide only a target figure for management purposes.



SOURCE NWRC, Stanford Research Institute.

FIG. 15 EQUIPMENT ITEMS COMPLETED vs. TOTAL MAINTENANCE WORKLOAD AT 1st FSR

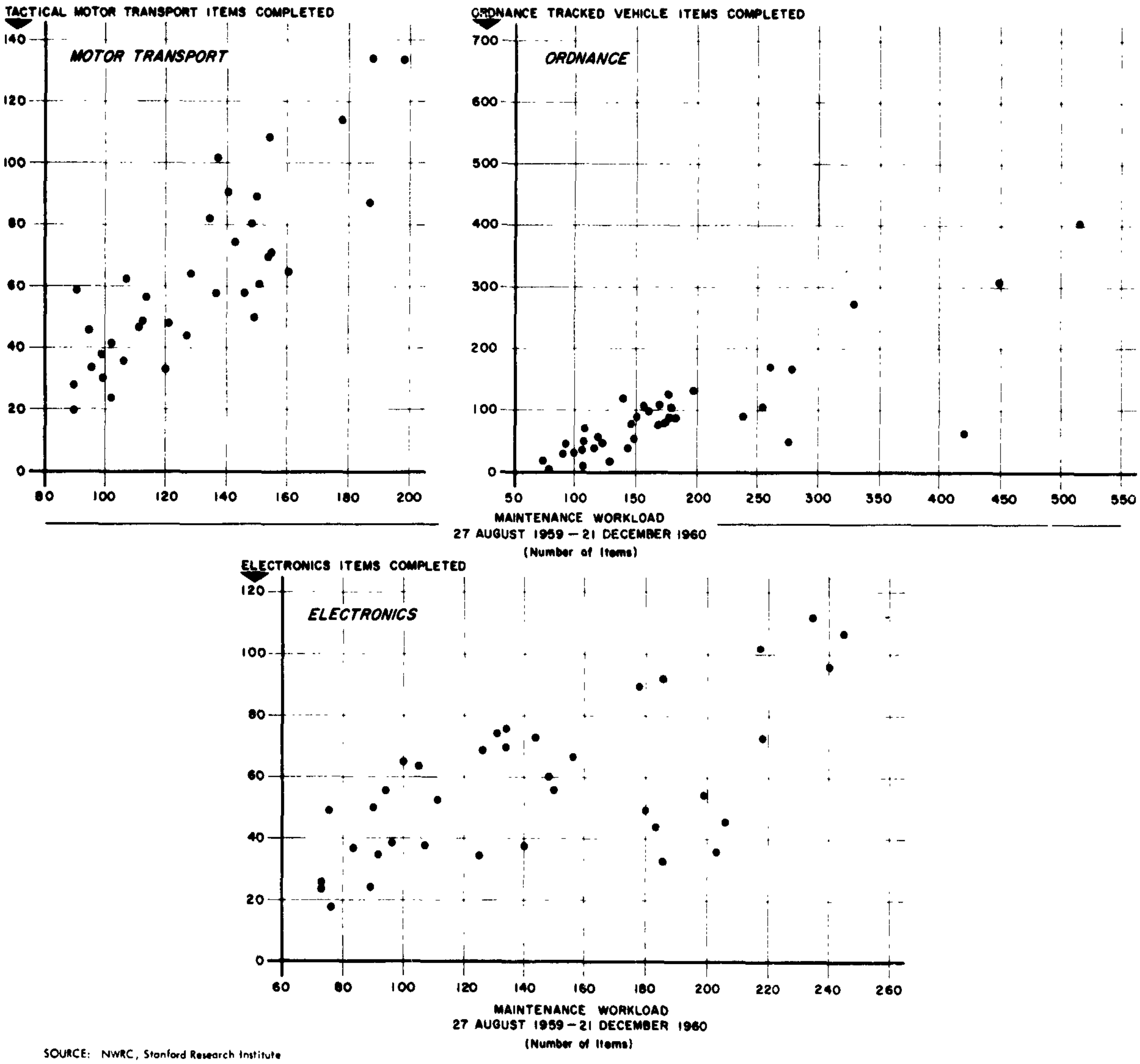


FIG. 16 EQUIPMENT ITEMS COMPLETED vs. TOTAL MAINTENANCE WORKLOAD AT 2nd FSR

FLOAT = UNSERVICEABLES *MINUS* MAINTENANCE CAPABILITY
OR
= BACKLOG *PLUS* EVACUATED

MINIMUM FLOAT = (UNSERVICEABLES *PLUS* BACKLOG) *MINUS* (MAINTENANCE CAPABILITY *PLUS* ADL *PLUS* ACCEPTABLE DEADLINE) *PLUS* SAFETY FACTOR

SOURCE: NWRC, Stanford Research Institute.

FIG. 17 DYNAMIC FLOAT

Originally, the float could be composed of the usual replacement and evacuation annual quota. The mix of equipment can be readily determined from the records of induction at field maintenance and adjusted periodically as the trend changes.

This system has the advantage of allowing evacuation of only that equipment which has actually reached unserviceability and which is beyond the capacity of the field maintenance organizations to repair per the issued criteria. Thus the system would tend to lower the evacuation rate of equipment by using up a more uniform portion of the service life of equipment. Actually, except for the problems of physically managing the equipment in the float, no penalty is paid for miscalculating float size, so long as errors are on the surplus side. Since equipment is not issued from the float until the need is present, any surplus issued into the float would not be used up until the need for equipment actually was present and it was placed into service as replacement for other equipment. Any surplus in the float remains available for later issue when the need for replacement occurs.

A closer calculation of float size could be made in which the minimum float would equal the sum of unserviceables generated during a time period equal to the stated preparation for embarkation of the organization supported plus the excess backlog at field maintenance, minus the sum of peak maintenance capability, any administrative deadline available, and the deadline acceptable to combat commanders, if any. A safety factor might be added. In effect, such a calculation would assure the supported units of being able to mount out in the materiel condition desired at any time in the future. In effect, what is described here is a transfer of a portion of the supply center ready-line closer to the field units where the equipment can be put into more immediate use in an emergency.

From the over-all program management point of view, this system of equipment replacement programing would have the primary advantage of allowing the program coordinator to manage equipment classes on the basis of the average experience expected of Marine Corps equipment in the future, and still replace that equipment on the basis of the individual condition of and need for the equipment items. Since issues from the float into service should contribute directly to improved serviceability of materiel of supported units, immediate replenishment of the float is not necessary. New inputs to the float could be spaced semi-annually or annually, or at other times compatible with 5th Echelon capability and the serviceable asset position of the Marine Corps. Actually, replenishment of the float is required only when calculations indicate an uptrend of unserviceables compared to maintenance capability.

Programing for the future could be based on FMF projections similar to the projections currently required by annual budget guidance. These aggregated forecasts would provide valuable inputs to the programing of 5th Echelon rebuild and/or procurement and thus would provide for the long-range requirements of materiel readiness. Such forecasts would not, however, be the basis for the actual shipment of replacement equipment into the dynamic float. The numbers and mix of equipment types for the various field units would be based on the actual calculation of need. This reduces the need to accurately preprogram the life experience of new equipment types about to be introduced. By placing a given percent of new equipment in the float and replacing from the float on the basis of actual need, each new equipment type, in effect, would produce its own rotation cycle.

The method of calculation for the dynamic float will allow identification of various factors contributing to materiel readiness. The calculation of the minimum float is based on several discrete conditions within the field unit for which the float is maintained. The contribution of each of these conditions to the required float size can be isolated, thus permitting more ready analysis of the causes for change. For example, one of the inputs to the float calculation is the number of unserviceables generated by user units. If a program of improved preventive maintenance is inaugurated in the user units, the effectiveness of this program should be reflected in a decrease in the number of unserviceables generated. On the other hand, an accelerated program of field training could be expected to increase the number of unserviceables generated within the user units. The net effect of two such changes would be readily identifiable.

A decrease in the excess backlog at field echelon maintenance could be traced, for example, to an improved spare parts availability. The effectiveness of a change in table of organization of a maintenance platoon or of a program emphasizing component replacement should reflect an increase in the maintenance capability of the field maintenance echelons. The process of isolating and labeling the various contributors to float size would thus afford a means for calculating the effect of various changes in the over-all Marine Corps materiel program.

BIBLIOGRAPHY*

1. "A Model for Assessing the Effect of Maintenance on Missile Launch Probability," The RAND Corporation, Santa Monica, Calif., 34 p. (23 September 1959), UNCLASSIFIED, AD-235 823.

2. "Administration and Operation of Transportation Equipment (Automotive, Construction and Railroad Equipment)," (BUDOCKINST 11200.2A), Dept. of Navy, Bureau of Yards and Docks, Washington 25, D.C., 342 p. (31 July 1957), UNCLASSIFIED.

3. Alchian, A.A., "Economic Replacement Policy," The RAND Corporation, Santa Monica, Calif., 129 p. (12 April 1952), UNCLASSIFIED.

4. "An Introduction to Equipment Analysis," Machinery and Allied Products Institute, Washington 6, D.C. (May 1956), UNCLASSIFIED.

5. "Armed Forces Supply Support Center Report on Management of Electrical/Electronics Materiel," Vol.VIII, 180 pp., Department of Defense, Washington 25, D.C. (7 March 1961), UNCLASSIFIED.

6. Boose, J.A., W.H. Sutherland, and R.B. Wing, "Analysis of Data Pertinent to Operational Mobility of M48 Tanks, " Operations Research Office, The Johns Hopkins Univ., Bethesda, Md., 70 p. (January 1959), UNCLASSIFIED, AD-221 698L.

7. Bovaird, R.L. and H.I. Zagor, "Downtime Distribution for Complex Electronic Systems," Report RM 59 TMP-59, G.E. Tempo, Santa Barbara, Calif., 16 p. (15 December 1959), UNCLASSIFIED.

8. Bovaird, R.L. and H.I. Zagor, "An Analytical Technique for Determining the Operational Availability of Complex Electric Equipment," Report RM 59 TMP-58, G.E. Tempo, Santa Barbara, Calif., 16 p. (11 December 1959), UNCLASSIFIED.

This bibliography was selected from a more extensive one and does not include Hq., USMC and supporting echelon directives concerning replacement and evacuation programs, and recoverable items programs, and similar directives concerning the formulation and implementation of the Marine Corps materiel program for Fleet Marine Forces.

BIBLIOGRAPHY (Continued)

9. Butterfield, P.H., R.H. Davis, D.A. D'Esopo, F.W. Dresch, B. Lefkowitz, and D.L. Pope, "The Development and Implementation of Advanced Inventory Control Procedures," Interim Report, SRI Project IU-2109, Stanford Research Institute, Menlo Park, Calif., 229 p. (December 1960), UNCLASSIFIED.

10. Chapman, A., "A Maintenance Improvement and Cost Control Program," ASME paper number 61-MPE-10, Amer. Soc. of Mech. Engrs., 29 W. 39th St., New York 18, N.Y., 8 p. (April 1961), UNCLASSIFIED.

11. Clegg, D., "Procedures for Development of a Weapon System Cost Methodology for Navy Weapons R59 TMP-19," Report R-59-TMP-19, G.E. Tempo, Santa Barbara, Calif., 49 p. (May 1959), UNCLASSIFIED.

12. "Company Procedural Manual on Equipment Analysis," Machinery and Allied Products Institute, Chicago (1951), UNCLASSIFIED.

13. Cooper, J.I., L.V. Rigby, and W.A. Spickard, "Proceedings of Shirt Sleeve Seminar on Maintainability," Northrop Aircraft, Inc., Hawthorne, Calif., 121 p. (23-24 August 1960), UNCLASSIFIED, AD-251-189.

14. "Employment of Force Service Support Units," (TIP(LOG)2), Marine Corps Educational Center, Marine Corps Schools, Quantico, Virginia, 62 p. (7 August 1959), UNCLASSIFIED.

15. "Employment of the Combat Service Support Units of the Marine Division," (TIP(LOG)1), Marine Corps Educational Center, Marine Corps Schools, Quantico, Virginia, 38 p. (26 September 1958), UNCLASSIFIED.

16. "Employment of the Marine Wing Service Group" (TIP(LOG)5), Marine Corps Educational Center, Marine Corps Schools, Quantico, Virginia, 20 p. (5 August 1958), UNCLASSIFIED.

17. "Engine & Accessories Standardization Program," Department of Defense, Washington, D.C., 280 p. (3 January 1961), UNCLASSIFIED.

18. Fabrycky, W.J., "Repair - Salvage Decision Criteria for the Reparable Item," Operations Analysis Office, HQ Okla City Air Mat'l Area, Tinker AFB, Okla., 23 p. (1 September 1960), UNCLASSIFIED, AD-245 983.

BIBLIOGRAPHY (Continued)

19. Goldberg, S.R., and B.H. Manheimer, "Revised Maintenance Concepts for the 1965-70 Time Frame, Volume 2" (U), Federal Electric Corp., Paramus, N.J., 62 p. (1 February 1961), SECRET, AD-321 416.

20. Harris, T.E., "A Method for Estimating Engine Failure Rates," The RAND Corporation, Santa Monica, Calif., 23 p. (9 October 1956), UNCLASSIFIED, AD-112 378.

21. Howard, W.J., "Chain Reliability: A Simple Failure Model for Complex Mechanisms," The RAND Corporation, Santa Monica, Calif., 30 p. (27 March 1953), UNCLASSIFIED, AD-111 172.

22. "Integrated Audit No. 2, U.S. Marine Corps 5th Echelon Repair Program; Program for Audit of Field Activities and FMF Units," Office of Comptroller, Dept. of the Navy, Washington 25, D.C., 7 p. UNCLASSIFIED.

23. Kirkwood, R.L. and L.W. Sepmeyer, "The Cost of Unreliability of Air Force Air-Borne Electronic Equipment as Presented by the Cost of Maintenance" (U), The RAND Corporation, Santa Monica, Calif., 1 vol. (3 December 1952), CONFIDENTIAL, AD-85 471.

24. "Logistic Support of the Landing Force," (TIP(LOG)4), Marine Corps Educational Center, MC Schools, Quantico, Virginia, 74 p. (20 June 1960), UNCLASSIFIED.

25. Losee, J.E., J.A. Buongiorno, and W.F. Frahm, "Maintainability and Supportability Evaluation Technique," Republic Aviation Corp., Farmingdale, N.Y., 1 vol. (May 1960), UNCLASSIFIED, AD-249 390.

26. Losee, J.E., J.A. Buongiorno, et al., "Maintainability and Supportability Evaluation Technique. Part III. Volume II," Republic Aviation Corp., Farmingdale, N.Y., 95 p. (June 1960), UNCLASSIFIED, AD-249 089.

27. "Machinery and Allied Products Institute Replacement Manual," MAPI, Chicago (1950), UNCLASSIFIED.

28. Manheimer, B.H. and S.R. Goldberg, "Revised Maintenance Concepts for the 1965-70 Time Frame. Volume 1," Federal Electric Corp., Paramus, N. J., 1 v. (1 February 1961), UNCLASSIFIED, AD-250 094.

BIBLIOGRAPHY (Continued)

29. "Maintenance and Maintainability. An ASTIA Report Bibliography," (U) 1 vol., 328 refs. (15 November 1960), SECRET, AD-320 320.

30. "Maintenance Logistics for Major Mechanical Equipment in U.S. Army Corps of Engineers," Report, Contract DA 44-009 Eng 3376, Operations Research Group, Dept. of Management, Case Institute of Technology, Cleveland 6, Ohio, 158 p. with Appendix, 220 pp. (30 September, 1960), UNCLASSIFIED.

31. "Maintenance Criteria," Ordnance Tank-Auto Cmmd., 1501 Beard Street, Detroit 9, Michigan, 228 p. (15 January 1959), UNCLASSIFIED.

32. "Marine Corps Manual," HQ, USMC, Washington 25, D.C., 150 p. (1 July 1961), UNCLASSIFIED.

33. "Marine Corps Supply Manual," HQ, USMC, Washington 25, D.C., (23 May 1961), UNCLASSIFIED.

34. "Marine Corps Fifth Echelon Repair Program, Integrated Audit Report No. IA2-61," Office of the Comptroller, Dept. of the Navy, Washington 25, D.C., 28 p. (6 October 1961), UNCLASSIFIED.

35. "Minimum Standards and Procedures Prescribed for Depot Reconditioning of Ordnance Tank-Automotive Materiel," Technical Bulletin, HQ, Dept. of the Army, Washington 25, D.C., 18 p. (6 February 1959), UNCLASSIFIED.

36. "Modern Army Maintenance System," U.S. Army, Frankford Arsenal, Philadelphia, Pa., 49 p. (April 1959), UNCLASSIFIED.

37. Mosbaek, E.J., "Economic Analysis of Repair Versus Discard Alternatives Polaris Fire Control System Components," Report RM 59 TMP-40, G.E. TEMPO, Santa Barbara, Calif., 33 p. (20 August 1959), UNCLASSIFIED.

38. "Policies Governing the Use of Commercial and Military Resources for Maintenance of Military Materiel," (DoD Directive 4151.1), Dept. of Defense, Washington 25, D.C., 10 p. (28 July 1960), UNCLASSIFIED.

39. Rachal, E.A. and W.E. Dougher, "A New Tool for Maintenance Cost

BIBLIOGRAPHY (Continued)

Control," ASME Paper Number 61-MPE-3, Amer. Soc. of Mech. Eng.s, 29 W. 39th St., New York 18, N.Y., 9 p. (April 1961), UNCLASSIFIED.

40. "Replacement Cost in Industry. Report of the National Council of Applied Economic Research," Ministry of Labour and Employment, Govt. of India, New Delhi, India, 87 p. (September 1960) UNCLASSIFIED.

41. "Review of Supply Management Activities, United States Marine Corps, Department of the Navy," Report to the Congress of the United States, The Comptroller General of the United States, Washington, D.C., 43 p. (August 1960), UNCLASSIFIED.

42. "Revised Maintenance Concept Study," Combat Development Div., The Ordnance Board, Aberdeen Proving Grnd., Md., 35 plus 96 p. (August 1959), UNCLASSIFIED.

43. Slattery, T.C., "The Role of Maintenance Analysis Polaris Fire Control System," Report RM 59 TMP-8, G.E. TEMPO, Santa Barbara, Calif., 21 p. (30 January 1959), UNCLASSIFIEL.

44. Slattery, T.B., "Rationale for a Fundamental Measure of System Maintainability," G.E. TEMPO, Santa Barbara, Calif., 21 p. (31 December 1959), UNCLASSIFIED.

45. Smith, K.M., "Simplified Preventive Maintenance Scheduling Systems," ASME paper number 61-MPE-9, Amer. Soc. of Mech. Engs., 29 W. 39th St., New York 18, N.Y., 8 p. (April 1961), UNCLASSIFIED.

46. Stedry, A.C., "The Use of Scientific Methods in Supply Management," Quartermaster Corps, Washington, D.C., 21 p. (9 May 1961), UNCLASSIFIED, AD-259 133.

47. Terborgh, G.W., "Business Investment Policy," Machinery and Allied Products Inst., Washington 6, D.C., 260 p. (1958), UNCLASSIFIED.

48. Terborgh, G.W., Dynamic Equipment Policy, 1st Ed., 290 p. (McGraw-Hill Book Co., Inc., New York, N.Y., 1949) UNCLASSIFIED.

49. "Unit Personnel and Materiel Reference Data for Fleet Marine Force Organizations w/CH 1," (MCS 3-9), USMC Educational Center, Marine Corps Schools, Quantico, Va., 465 p. (1960), UNCLASSIFIED.

BIBLIOGRAPHY (Continued)

50. vanTijn, D.E., "Special Interim Report on Cost Studies," ARINC Research Corp., 1700 K St., N.W., Washington 6, D.C., 34 p. (14 July 1961), UNCLASSIFIED, AD-261 062.

51. Weiss, G.H., "A Problem in Equipment Maintenance," Institute for Fluid Dynamics and Applied Mathematics, U. of Maryland, College Park, Md., 21 p. (February 1961), UNCLASSIFIED, AD-252 680.